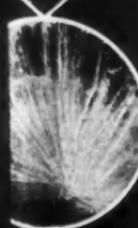


# CHEMISTRY



SEPTEMBER  
1949



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## *Citizens of the Second World*

► THE EARTH is today populated by descendants of those who, for one reason or another survived the Black Death. Out of the millions swept by the epidemics of the Middle Ages, chance laid a finger on one here, another there and permitted them to escape destruction. Their friends and neighbors, no less brilliant or worthy, no less pious and possibly no more dirty, vanished from the earth.

Such is the effect of radiation in massive doses. In the accounts quoted in this issue of CHEMISTRY from the Sixth Semi-Annual Report of the Atomic Energy Commission, the effect of radiations on the body is stressed. Out of given colony of laboratory mice exposed to a certain dosage of radiation, 8% will die. The heavier the dosage, the higher the percentage. The finger of chance points out one here, another there.

So long as the handling of radioactive material is carried out in the laboratory, monitoring devices can control individual exposure to these potentially death-dealing rays. Loosed and thrown about as weapons by the irresponsible, only the finger of chance will protect friend and foe alike. The statistical percentage of those exposed to the radiation will die. The survivor will scoff at the seriousness of atomic weapons, until nemesis overtakes them in turn.

The citizens of the Second World will be those who, out of the world's population, have not suffered lethal doses of radiation. Their escape will have no relation to their politics, but, if those who survive are predominantly medieval in outlook, we will lose the vision of those who are now exploring the Second World.

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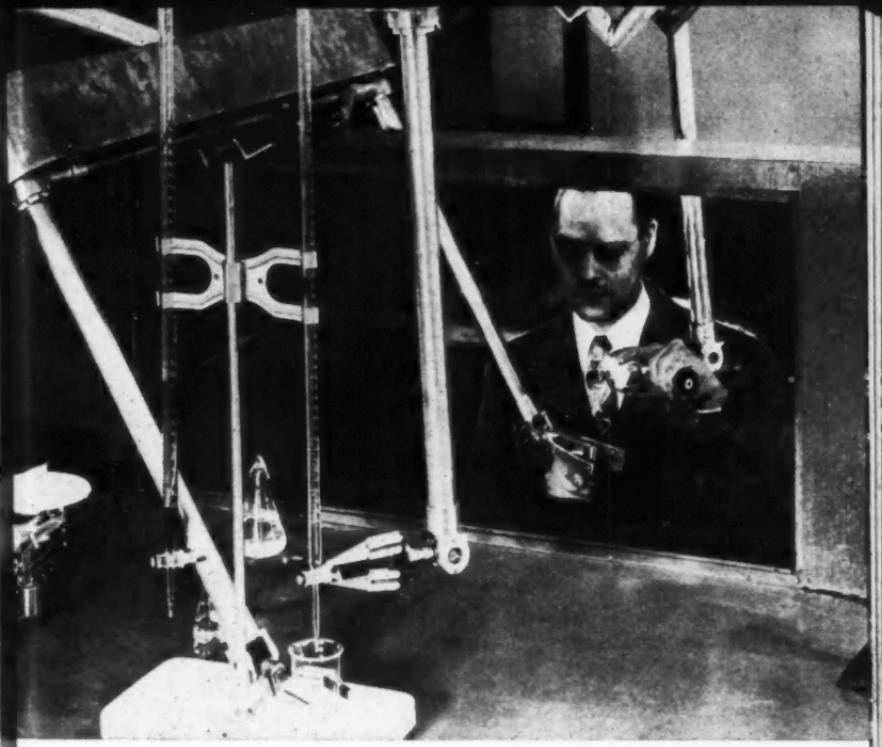
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—Photo Courtesy of Argonne National Laboratory.

► "MASTER-SLAVE manipulator" allows worker at the Argonne National Laboratory to turn a petcock or perform other delicate operations from a safe distance in a "hot lab."

## A Second World

by DR. ALAN GREGG

Chairman, AEC Advisory Committee on Biology and Medicine, in  
Sixth Semi-annual Report of the Atomic Energy Commission.

► THE PHILOSOPHER Santayana has remarked that he who feels prepared to ignore history is doomed to repeat it. In the history of scientific discovery there are lessons that the Atomic Energy Commission is heeding, deliberately and energetically, lest the frustrations and futilities that attended other dis-

coveries repeat themselves in the study and development of atomic energy.

Sulphuric ether was discovered by Valerius Cordus in 1540. For over 300 years it remained a chemical commonplace, dangerously inflammable, almost unused, though employed playfully by students as a brisk and potent

V

intoxicant. Then Crawford Long and W. T. G. Morton in 1842-44 found and showed its wonderful value as an anesthetic. It may take long years to make a substance that is known to science useful to man. Think of the sum total of unnecessary pain during 300 years of the failure to explore the effect of ether on man. Once a new substance is made, or a new process invented, years—even centuries—may elapse before all its properties or uses have been discovered and put in practice.

Roentgen discovered X-rays in 1895. The immediately obvious application in the detection and correction of fractured bones was made rather promptly. In 1902 Cannon, by using X-ray photographs of barium swallowed by experimental animals, defined one of the effects of strong emotions on the stomach and intestines. He thus laid one of the foundations for psychosomatic medicine—a far cry from classical physics. Still later in the use of hard X-rays upon tumors and soft X-rays upon the skin and hair, physicists and physicians found uses of X-rays not dreamed of by Roentgen or his contemporaries. The uses a new substance may possess are as unpredictable and yet as certain as the future shape of a tree lying invisible in its seed.

Gasoline—at first a worthless and dangerous byproduct of distilling kerosene from crude petroleum—was thrown away by the millions of barrels, until its value was shown when used in engines designed to turn its explosive energy into mechanical work. As both result and cause of developments of the internal combustion engine, came the automobile, the tractor,

and the airplane—long after gasoline was first produced and thrown away.

However, with energetic and alert study the gap between a discovery and its major application may not last long. Only 14 years elapsed between Fleming's discovery of the antibiotic effect of a common mold and the production of penicillin in significant quantities for use in human therapy.

But we cannot safely overlook the possibility of danger lurking in any activity that leads to discovery. Research experiments may create substances or unleash forces so powerful in their effects on living tissues that investigation of their properties is no idle curiosity or speculative diversion. It is an impelling necessity. We cannot afford to be casual or careless. The appalling burns from the ignorant or casual use in the early days of X-ray and radium stand on the record as a sombre warning.

If scientific research offers unimaginable opportunities for good, it imposes unexampled obligations to protect ourselves against equally unforeseeable dangers. Thanks to example (from other fields) of wasteful waste and reckless inadvertence, the Atomic Energy Commission is devoting extensive and unflagging attention to the biological and medical effects of radiant energy—both those that may prove to be beneficent and those that may maim or kill. When man first discovered fire he began a long apprenticeship to caution in dealing with what is both useful and dangerous—and the end is not yet.

The story of the Garden of Eden and the myth of the Promethean fire find uncanny parallels in the huge re-

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sponsibilities of the Atomic Energy Commission to control the unprecedented forces of atomic energy for the welfare of man. To control the use of this power, to explore its nature, its implications and potential applications, and at the same time to protect us all against its dangers—these responsibilities set a series of tasks that also are without precedent and all but immeasurable.



► GROWTH REGULATOR containing radioactive atoms is traced as it moves through the plant. Dr. John W. Mitchell of the Plant Industry Station at Beltsville, Md. sections plants so that the radioactivity of each part can be measured separately.

The Commission is charged by law with the exclusive control of materials, equipment, and processes which are unique, constantly dangerous, and certainly not yet sufficiently understood. To this task is added the difficult circumstance, foreign to most other scientific enterprise, of secrecy. Therefore, the Commission has every reason to assume extensive responsibilities for the further development

and study of atomic energy and its products and their effects on human beings, animals, and plants. The principal activities in meeting these responsibilities and hastening the discovery and application of useful substances and processes may be listed as follows:

- (a) The health protection of personnel engaged in the preparation, transport, use, and research on the use of fissionable material and its products.
- (b) The study of the effects on human, animal, or plant tissues of atomic bombs used in the war and in tests made subsequently.
- (c) In view of the known sensitivity of cells at the time of their division, the study of the effects of various types of radiant energy on the processes involved in heredity, and the study of the effects of radiant energy on abnormal cell reproduction, e.g., cancer.
- (d) The preparation of tagged atoms or isotopes for the purpose of biochemical studies not otherwise related to radiation effects, and the study and use of isotopes where these are directly related to the biological or medical consequences of radiation.

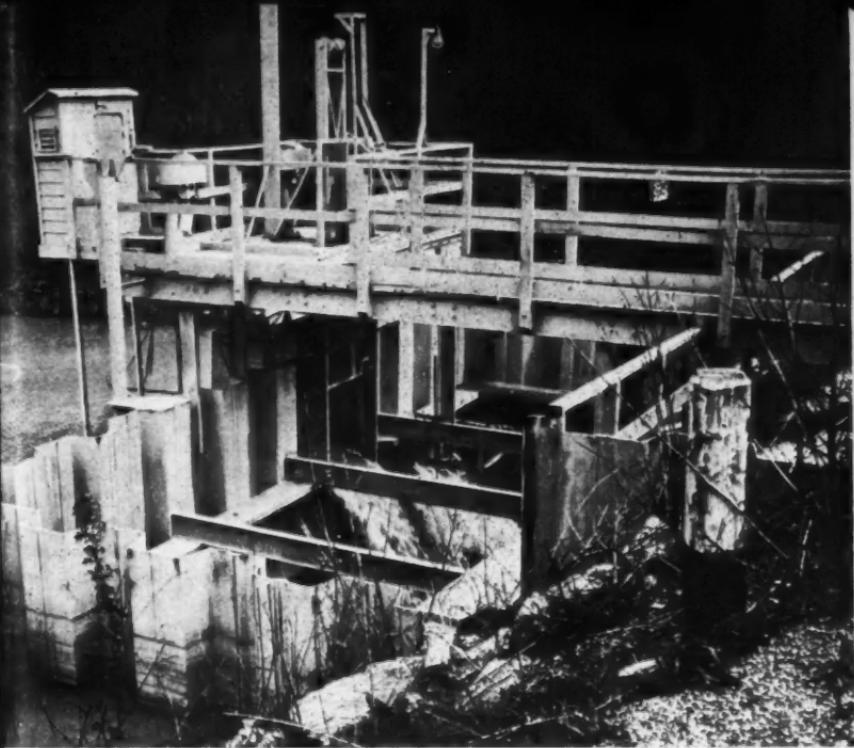
Perhaps the kernel of the situation lies in the fact that the greater man's knowledge of the laws of nature the more substances he can create that have never actually been found in nature. We can thus not only make completely unfamiliar substances but also release forces that in quality or intensity are not to be found in the natural world. Virtually a second world for study and exploration comes thus into

being as a result of profoundly understanding the laws that govern the phenomena of the world about us—the first world we studied and explored. Nor is this the end of the possibilities before us. There is almost an infinity of possible applications of new substances and new forces. Indeed the case for finding the uses of new substances for human needs, the harnessing of new forms of energy to serve human purposes, rests in the phrase of Protagoras the Sophist: *homo mensura*—"man is the measure of all things." And what is to measure the needs and purposes of man?

### Radiation and Life

Atomic energy is not a new thing. Long before man existed, the radiation of cosmic rays—a form of atomic energy—was striking down upon the earth from the skies; radioactive elements like radium in the earth itself gave off their radiation—another form of atomic energy. This radiation from sky and earth still goes on everywhere in the world. It is least at sea level, one-tenth as strong, for instance, as in the Colorado Rockies where thinner air lets through more cosmic rays and radioactive deposits exist in the earth.

Atomic energy is not new, but never before have there been so many sources of radiation, nor has it been released at so rapid a rate. In the earth, radiation is released slowly by the gradual disintegration of some 16 elements which, like radium, are normally radioactive. Man has added enormously to the numbers of radiating substances by creating new radioactive varieties of almost all elements, and he also has increased enormously the amounts of radiation from other sources. Man has



—Photo by Westcott, Oak Ridge.

► WATER contaminated by radioactive materials cascades thru a sluice box into ponds where it is constantly checked by automatic instruments.

concentrated radium, has created X-ray machines, atom-smashing machines, and nuclear reactors. In the nearly 50 years that man has known about radium, for example, he has extracted no more than a few pounds in the entire world—but one reactor generates as much radiation as would several hundred tons of radium.

In addition to increasing the amount of atomic energy and the number of sources, man is finding new and extensive uses for radiation, and is bend-

ing all efforts toward discovering even more ways to employ it for the benefit of human kind. More and more people are coming into contact with these radiating materials: when scientists use radioactive materials as "tracers" to probe into the formation of metals and alloys, and into the hidden processes of plant life and human life; when physicians use these same materials to investigate, to diagnose, and to treat disease. Science, medicine, and industry, all are using atomic energy.

Above all this is the possibility that man may again be forced to employ or defend himself against atomic weapons in warfare.

It is clearly important that we should learn all that we possibly can, not only about the peaceful uses and benefits of atomic energy, but also about the harmful effects of the radiation we have set free, and how to protect ourselves from these unseen, deeply penetrating rays of energy.

### The Growth of Knowledge

We have learned this lesson of self-protection slowly and painfully. The first X-ray burn was reported in 1896. But before there was general recognition of the danger in 1915, scientists had died from the deeper effects of X-ray and radium, and many more people were injured by X-rays in hospitals during the first World War. Strange stories went the rounds—that radiation was stimulating to the body; false stories, but people believed them. So, in the 1920's a tonic water containing minute amounts of radium was sold at fantastic prices as a miracle cure-all. People died lingeringly and painfully from drinking that water. Others, still alive, are suffering from bone diseases that may prove fatal.

In a factory, workers painted on clock dials the luminous numbers that could be seen in the dark. Following immemorial custom, the painters pointed the delicate brushes with their lips—and swallowed minute quantities of radium. Nearly a score of them died.

This damage was caused by radiation, but even more it was caused by ignorance.

The Atomic Energy Commission has the clear responsibility to inform

people, not only about the progress made in promoting the national defense and security through the production and improvement of atomic explosives and weapons, but also about the benefits and the dangers of radiation. In this report, therefore, the Commission reviews the activities in biology, medicine, and health physics—which is the technique of protecting people and animals against radiation—and attempts to outline what has been learned and what accomplished in these fields.

### What Is Radiation?

In atomic energy work, we are concerned basically with *high energy radiation*. A stove radiates heat; an electric bulb radiates light and heat. But these are weaker forms of radiation. High energy radiation, in the sense that we discuss it here, is the same thing as atomic energy, the same thing as radioactivity. High-energy radiation comes from the core, the nucleus, of the atom.

All material things—the human body, an electrical wire, a chair, water—are composed of certain basic constituents which we call *elements*. Iodine is an element, copper is an element; water is composed of two elements, oxygen and hydrogen; table salt of two others, sodium and chlorine. These elements in turn are composed of very minute particles called *atoms*. Once people thought the atom was the smallest bit of matter, but now they know that the atom itself is made up of outer shells of *electrons* which revolve about the nucleus of the atom, and that the nucleus, too, is made up of particles—mainly *protons* and *neutrons*—which are held together by a store of energy. When we set this ener-

gy free by splitting the atom, or when we jar loose these particles from their normal orbits, we release high energy radiation.

All high energy radiation has the same kind of effect on living cells and living tissue. Some forms of radiation may cause greater amounts of damage, but the type of injury is the same.

Basically, this report will discuss five classes of radiation that are most frequently encountered in biological and medical research:

- (a) *Alpha particles*—large, highly damaging, positively charged particles. They are unable to penetrate the unbroken skin but if an element liberating them is deposited within the body they may cause extreme damage.
- (b) *Beta particles*—moderately damaging, moderately penetrating, negatively charged particles. They will go through about a third of an inch of tissue.
- (c) *Gamma rays*—highly penetrating. They are less damaging, quantity for quantity, than the above types of radiation.
- (d) *Neutrons*—uncharged, high-speed, penetrating, highly damaging particles. Depending on their speed, they can penetrate several feet of tissue.
- (e) *X-rays*—similar to gamma rays, but less penetrating.

### Effects of Radiation

These kinds of radiation affect all living things in basically the same way. This is because all living things are formed of very much the same materials.

Carbon, for example, is a constituent of all living things. The nucleus of a

carbon atom carries six units of *positive* electricity. Whirling about the nucleus and forming the atom's outer shell are six electrons, each bearing a *negative* unit of electricity. The combination of these equalizing electrical units—six positive, six negative—makes the carbon atom as a whole electrically balanced and neutral. This electrical balance, this equalization of positive and negative charges within the atom, is characteristic of all atoms—of hydrogen, nitrogen, and oxygen as well as carbon. Living things use atoms of these elements to build the protein molecules which are the major constituent of their tissue, and these molecules, too, are exactly balanced. The negative charges of their thousands and millions of electrons exactly equal and balance the positive charges in the nuclei of their atoms so that the molecule as a whole is neutral electrically.

In the rapid and continuous processes of life—in the building up and breaking down of tissues, the replacement of nutrients and removal of wastes, the production of muscular energy, the reproduction of the whole organism—these complex living molecules break up and recombine in a million ways. Yet always, they combine in ways that preserve their electrical balance. To destroy that balance would damage or kill the living material.

This is what radiation does. Radiation attacks, disrupts, and destroys the delicate electro-chemical balance in the atoms, molecules, and protein combinations within the bodies of living things. As a result, it damages and kills the cells of which atoms and molecules are a part. If enough cells

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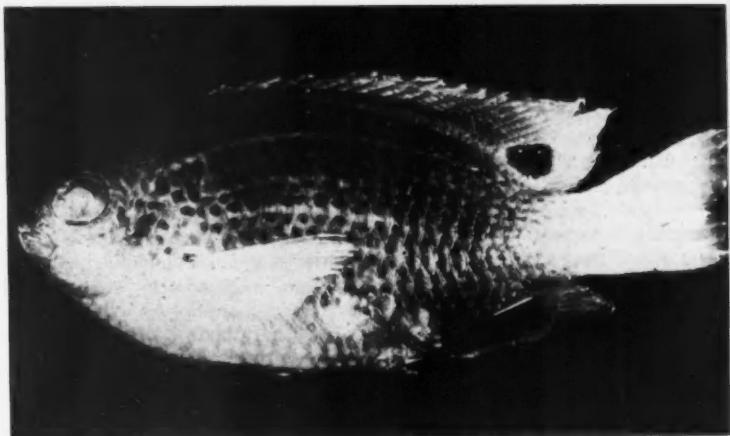
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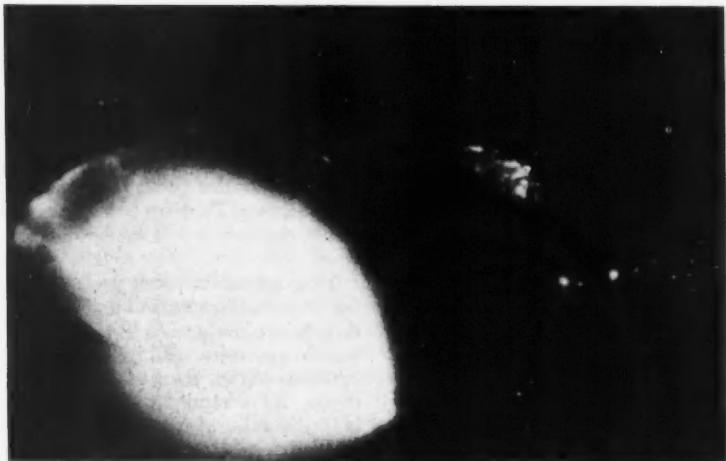
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—Photo courtesy of University of Washington.

► *Fish which ate radioactive material were caught in Bikini lagoon after the atomic bomb explosion. This damsel fish shows by its radioautograph how such material becomes concentrated in the digestive tract.*



are destroyed, the whole organism—plant, animal, man—is severely injured or dies.

### **Ionizing Radiation**

In passing through living tissue, radiation not only destroys the electrical balance of the atoms and molecules, but it breaks them into fragments which carry positive or negative charges. These fragments are called positive and negative ions, and the radiation that makes them is called *ionizing radiation*.

A positive ion will normally tend to combine with a negative ion to form a new molecule that is electrically neutral. In the living cell, if the two ionized parts of a broken molecule were to recombine within a very short time, perhaps no lasting damage would be done to the cell. The chances for this are remote, however, because intense ionizing radiation breaks down many different molecules and these multitudes of free ions recombine in haphazard ways. This not only completely disrupts the delicately organized tissue, but may also form new compounds that are highly toxic in themselves and will poison otherwise healthy tissue.

Moreover, ions impelled by collision with radioactive particles penetrate other tissue where they have an effect very similar to ionizing radiation itself.

### **Need for Basic Research**

Unfortunately, beyond the general facts cited, we do not know the exact mechanism by which radiation harms living molecules, cells, and tissue. Much work of practical value has been done on a purely empirical, or trial-and-error, basis. Scientists know, for

example, that bone marrow cells and other rapidly growing tissues are more sensitive to radiation than are brain cells, and that other kinds of tissue differ from one another in their resistance. Cancer cells are usually far more susceptible than normal tissue, and radiologists have used this knowledge in treatment of cancer by X-ray and radium.

But we need to know much more about these processes, and much of the diversified biological and medical research sponsored by the Atomic Energy Commission points toward supplying essential information in these fields. Until we know how radiation acts in living tissue we cannot fully understand the mechanism of heredity in plants and animals; or the chemistry and mechanics of what "radiation sickness" does to people and how best to treat it; or the nature of growth; or the cause, diagnosis, and treatment of cancer.

In the last 20 years, radiologists have codified rule-of-thumb methods for working with X-rays and radium. Under the impact of the atomic energy program, with the thousand or more new radiation-emitting materials it has discovered or created, new knowledge is revising former views. Out of wider experience, for example, experts estimating the amount of radiation a man could tolerate day in and day out without suffering injury have revised the standard to provide an even greater margin of safety. They have cut in half the level of radiation formerly allowed. Many research projects, at AEC National Laboratories or supported under contract by the Commission are seeking to evaluate the effects

of different radiations, and to establish appropriate standards and rules. But here again, the investigators are deeply aware of a lack of basic, fundamental knowledge of the mechanism of radiation effects.

Today, research into radiation is straining the manpower and financial resources of the Nation's scientific institutions. Even so, it will be many years before even half the problems now demanding solution can be studied. The Atomic Energy Commission has attempted to look over the entire field of this research and to undertake, or to support where necessary, those

projects which seem to promise the maximum advance in knowledge.

Contractors operating Commission-owned laboratories conduct such research; the Commission also contracts with private institutions for specific research projects. All this research is of the utmost importance, but the Nation depends chiefly, now as in the past, upon the independent private research institutions of the country, supplemented by published results from abroad. This report's survey of the Commission's program ranges over the greater part of the field of basic research in biology and medicine.

### *On the Back Cover*

► TARGET for measuring effect of radioactivity on growing plants. Radioactive cobalt is placed at the center, plants are set out in the concentric circles, effect on their growth is observed—Photo Courtesy of Brookhaven National Laboratory.

### *Let Us Take Counsel*

► THE PRESENT state of our knowledge about atomic phenomena is often compared to that of the world when fire was discovered. A faint echo of that early time has been preserved for us in *Gilgamesh, an epic of old Babylonia*, which has been beautifully translated into English verse by William Ellery Leonard. The hero of that legend, who journeys to a volcano, a mountain of fire, has a vision of the consequences. His description applies as prophetically to our own atomic age.

*"My friend, I saw a third dream  
And the dream which I saw was horrible  
The heavens shrieked, The earth bellowed  
A storm gathered, Darkness came forth  
A flash flamed, A fire shot up  
The clouds thickened, It rained death  
Then the brightness vanished, the fire went out  
The blaze that had fallen turned to ashes  
Let us climb down  
That we may take counsel on the plain."*

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## Symptoms of Sickness Induced by Radiation

# Acute Radiation Illness

From the Sixth Semi-annual Report of the Atomic Energy Commission.

► ACUTE RADIATION syndrome indicates an acute illness which may end in death or recovery of the patient after a few weeks, or it may result in chronic illness which may be fatal after a prolonged period.

The acute syndrome differs radically from previously known types of radiation injury—such as chronic radiation illness which arises after repeated or continuous exposure to radiation and gradually develops as a lingering illness. Radiation injury to a part of the body may be either acute or chronic, as when burns or ulcers result from misuse of X-ray machines. The ulcerated cancers of the skin which developed on the hands of the old-time radiologists and radium technicians are typical examples of the chronic ailments from this type of injury.

### Causes of Acute Syndrome

The acute syndrome indicates a much more extensive and severe ailment than any other of these radiation illnesses. It can be caused by heavy radiation from outside the body, or by a much lesser amount of radiation from certain radioactive substances taken inside the body.

*External.* A man can suffer an acute radiation syndrome by being exposed to radiation from an atomic explosion, from an unshielded nuclear reactor, from a large quantity of radioactive material, or from an X-ray machine operated too long or at too high energy. If the radiation comes from out-

side the body, it will produce the acute syndrome only if the rays or particles are penetrating enough to strike deep into the body and damage such sensitive tissues as the marrow of the bones. Fast neutrons can do this, so can gamma and X-rays.

*Internal.* The acute syndrome can also result from a man taking into his body certain kinds of radioactive material that enter his tissues and bones rather widely and become fixed there. Even a small amount of some radioactive materials will cause as acute an illness as exposure to the radiation from an atomic blast.

The rays or particles also need not have great power of penetration because the material that gives them off already is deep within the body where it can do the most damage. Plutonium, for example, gives off alpha particles which can pierce only a few thousandths of an inch of tissue. But because plutonium lodges in the bone and stays there, it can destroy the marrow that manufactures red blood cells. Similarly, other radioactive materials that lodge in peculiarly sensitive parts or organs of the body can cause severe injury.

### Unique Aspects

Heavy exposures to either kind of radiation cause a massive breakdown of the body's tissues, particularly in certain organs of the body. Since destruction of cells in various tissues reaches its height at different times

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after exposure, symptoms from these injuries will occur at different times as the illness grows worse. Two features make this type of body damage unique:

**Tissue damage.** No two organs or tissues of the body suffer exactly the same amount of damage. Lymphoid tissue, bone marrow, the sex organs, and the lining of the small intestine suffer heavy damage. Muscles, nerves, and fully grown bone are not so easily injured. Other tissues, such as skin, liver, and lung, lie in between these extremes.

**Delayed tissue death.** Unless the radiation has been extremely heavy, cells may not die for hours or days. For a week after skin is injured by X-rays, it may show only a surface reddening and swelling of the underlying tissues. Blistering and loss of dead skin may be delayed for 2 weeks.

### Varying Severity

A man suffering from acute radiation illness may have only a few symptoms, real enough to him but undetectable by the doctor. Or he may have a severe general illness that ends in death or in a long convalescence. The total amount of radiation he suffers is, of course, the thing that makes the greatest difference. Other factors that play a big part include:

**The dose rate.** A heavy dose of radiation delivered at one time will cause much more damage than the same dosage divided up and administered at intervals. A certain degree of tissue recovery may take place in the intervals between such periodic doses.

**Type of radiation.** Neutrons and alpha particles are more damaging to tissue than are gamma or X-rays, although

the nature of the injury is very similar in each case, and alpha particles do not penetrate.

**Individual response.** Scientists believe some people have more resistance than others to radiation. This is rather definite where small amounts of radiation are concerned and may be true of the dosage necessary to cause death. Laboratory tests have proved, for example, that a dosage of radiation ordinarily fatal to man will kill 8 per cent of a certain very pure strain of mice. To kill all the mice, it was necessary to more than double the dosage. Similarly, with lighter radiation, it was found there was a dosage that would kill none of the mice. As radiation increased, larger and larger percentages of each group of mice died.

### Course of Illness

The course of illness in acute radiation syndrome can be described from the case records of a few people injured in radiation accidents, and of Japanese exposed to atomic bombings, where their injuries were uncomplicated by blast damage or flash burns. Only a small percentage of the Japanese in Hiroshima and Nagasaki suffered from radiation illness alone. Basing their report on these records, physicians describe the illness of a typical severely injured patient as going through four phases.

**Phase I.** Within an hour or so after exposure, the patient becomes nauseated, vomits, and suffers general prostration and weakness. Diarrhea may occur and his blood pressure may fall a little. In general, the heavier the dosage, the more ill the patient will be. This phase is quite similar to the "radiation sickness" suffered by patients

treated intensively with X-ray or radium.

**Phase II.** After the first onset of the illness, symptoms tend to disappear, and for a period of a few days to several weeks the patient feels less ill. For patients who have suffered the heaviest radiation, this period will be short. Reports have stated that Japanese injured by radiation alone were entirely without symptoms during this time, but the best information is that they were sick people who, because of the emergency, drove themselves to do what had to be done.

**Phase III.** The illness reaches its height during this phase. Whether or not the patient survives depends on his ability to endure this acute stage. The patient becomes apathetic and develops a fever and rapid heart action. He becomes increasingly weak and loses weight. He loses his appetite, may become nauseated and suffer severe diarrhea which is sometimes bloody. Small hemorrhages may appear in the skin and the gums bleed. In severe cases, infected ulcers may spread throughout the mouth. The hair may fall from the head and body about 3 weeks after exposure.

The slightly injured recover quickly, but those who received a heavier dose of radiation may continue gravely ill for weeks. The most severely injured may grow progressively worse over a period of weeks and finally succumb, or may die within a few days.

**Phase IV.** Patients who survive enter a convalescence during which a feeling of weakness and fatigue are the outstanding symptoms. It may be months before the patients recover normal strength and weight. The skin

hemorrhages disappear and the hair, if lost, gradually regrows. Usually within 6 months, the patient feels completely well. All usual methods of examination indicate that, by this time, the patient is normal. Even examinations 2 years later have revealed no remaining physical abnormalities. Nevertheless, it is too soon to say that survivors will not suffer further ill effects.

#### Other Reactions

Besides the symptoms described, the acute radiation illness includes damage that can be detected only by laboratory tests—changes in blood cells, in male sex organs, and in the functioning of other organs.

Several symptoms of the third or acute phase of the illness stem directly from injuries to certain elements in the blood. Infections and ulcerations arise because radiation destroys the white blood cells that normally hold bacteria in check. A few days after radiation exposure, the white cells decline and, in severe cases, disappear almost entirely. The skin and gum hemorrhages are seemingly connected with a fall in the number of platelets in the blood, since these fragments of bone marrow cells help the blood to clot, although other causes such as an increase in an anticoagulating substance that resembles heparin, a normal blood chemical, also contribute. Platelets begin to decline only after an interval of weeks and, where the patient survives, reappear during convalescence. A third and very serious effect upon the blood, the decline in red cells, causes anemia and contributes to the general weakness and debility so marked in acute radiation illness. The decline of red cells starts immediately after exposure and may continue for months.

Microscopic studies of tissue, amplified by more complete research with animals, indicate these blood changes are caused by radiation damage to the bone marrow and to the lymphoid tissue where these various cells are born. And the injury to tissue, as well as the course of illness in the patient, can be traced to damage to the cells. Radiation causes the cells to swell, disorganizes their structure and stops them from reproducing themselves. The stoppage of cell division occurs immediately after irradiation; structural changes appear more gradually. The most spectacular change is the collapse of certain parts of the cell, and the shrinkage of the nucleus followed by death and disintegration. The interruption of cell division is temporary, but when new cells begin again to divide they often show bizarre changes in their inner structure.

## Exploding Atoms Mailable Now

► EXPLDING atoms may now be sent by mail. New Post Office regulations allow isotopes, clock dials, uranium ores, luminous compounds, and radium paints to be mailed if their radioactivity is weak enough.

The amount of radiation at the surface of the package is limited to one-tenth of the maximum that is considered safe for human body exposure daily. In terms of the measurement of radioactivity, this is 0.010 of a roentgen during one day.

This is less radioactivity than would fog an undeveloped photographic film in 24 hours.

Uncle Sam's mailmen have relaxed their stringent embargo on

## Treatment of Injuries

Scientists have devoted a great deal of experimental work to methods of treating radiation injuries. They have found no practical way to prevent the death of cells or tissues heavily injured by radiation. However, the regenerative powers of the body are very great and if it can be helped to survive the acute stage of the illness, even the most radiosensitive tissues may be able to resume their normal functions.

Many treatments help the body through the acute stage of the illness. Blood transfusions supply red blood cells. Penicillin limits infections. Certain materials, such as toluidine blue, help to reverse the tendency to bleeding. Physicians also maintain the water and salt content of the patient's body—substances apt to be lost in any serious illness. Maintenance of adequate nutrition, especially of those substances used by the body to manufacture protein and cells, also are helpful.

## Exploding Atoms Mailable Now

radioactivity because of an increasing demand from industry to allow the mildest sort of radioactive materials to be carried in the mails. Heretofore, except for very small quantities of luminous paint and polonium, a radioactive element, radioactive materials have had to be sent by express.

The radioactive materials sent by mail may be in the form of liquids, solids or gases, but they must be properly packaged and labeled. The gamma radiation must be less than 10 milliroentgens for 24 hours at the surface of the parcel, and there must be no significant alpha, beta or neutron radiation.

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## Bigger Atom Smasher; More Useful Isotopes

# Advances in Nuclear Science

A 70,000,000-volt synchrotron, one of the newest of atom-smashers, soon will be brought into the fight against cancer.

Such a machine has been ordered for the University of California Medical School at San Francisco. It will be financed by the Atomic Energy Commission and constructed by the General Electric Company.

The machine will be used to explore thoroughly the indications that very high energy radiations go through normal tissue without doing much harm to them, and have nearly all their effect deep in the body.

Experiments with X-rays up to 20,000,000 electron volts have already demonstrated that this happens. Scientists feel that this principle offers great promise in the treatment of deep-seated cancers, in which one of the greatest problems is to destroy the cancer without killing the normal cells essential to the patient's well-being.

Only recently have suitable machines of high enough energy for this purpose become available. They are a product of post-war atom-smashing developments.

The director of the research program for the new machine will be Dr. Robert S. Stone, noted professor of radiology at the University's Medical School and wartime head of some of the important health and safety phases of the atomic bomb project.

The new concept has been demonstrated in animal experiments using

X-rays produced by betatrons up to 20,000,000 electron volts. The new synchrotron will be the first such machine applied to this work, and it will be capable of adjustment to any energy between 5,000,000 and 70,000,000 electron volts.

Because the concept is still in the experimental stage, Dr. Stone will begin work with animals. Human applications will be made as soon as the animal experiments warrant.

The project, including the machine and building to house it, will cost about \$445,000. Completion is scheduled for 1951.

### Hornets Trace Leaks

"Hot" HORNETS—in the radioactive sense, not just with their stingers—promise to be useful in the safety program of the Atomic Energy Commission. The potential helpfulness to man of these energetic but not-too-popular insects is disclosed in the semi-annual report of the AEC.

One curious but until now apparently useless fact of natural history was the knowledge that the common white-faced hornet accumulates the element barium in its body. Barium, a chemical relative of the more familiar and abundant calcium (lime) is widely distributed in nature. It is also one of the lighter elements formed in the radioactive breakdown of the heaviest natural element, uranium, the atom-bomb metal.

Researchers on military and peaceful uses of uranium naturally do not want

escaping atomic fragments strewing the countryside with dangerous pollution. So it is proposed to encourage colonies of hornets to live in the neighborhood of nuclear-fission laboratories, and to seek their food among plants exposed to possible radioactive leaks. From time to time some of them will be captured, killed and analyzed. If they assay too high in barium, there's a "hot" leak somewhere, that has to be found and stopped.

Description of various safety measures used in atomic energy laboratories and power plants occupies a substantial part of the AEC report. Because they know how dangerous is the stuff with which they are dealing, scientists and other workers around the laboratories normally take elaborate precautions against exposure, and the number of casualties to date has been gratifyingly small.

#### New Coolant Developed

One new development, not yet in use, has been the finding of a new, reusable coolant for the atomic piles, to replace the water- and air-cooled systems hitherto employed. This is expected to simplify the coolant-disposal problem.

#### Zirconium is Antidote

Encouraging experimental results have been obtained with the somewhat unfamiliar element zirconium as an antidote for the highly poisonous man-made atom-bomb element, plutonium. Zirconium injections into the bodies of

plutonium-poisoned rats result in the release of the plutonium from the tissues where it was bound, especially in the bones, and permit it to be eliminated by way of the kidneys. Considerable amounts of plutonium were thus eliminated even in cases where it had been tied up in animals' bodies for many months.

#### Elements Combat Cancer

Radioactive isotopes of various elements have been found valuable in combatting cancer. Radioiodine has been particularly useful as a means for concentrating radio-active attack on certain types of malignancies, and radiophosphorous has helped surgeons to locate hidden tumors during brain operations. Radiocobalt has been found suitable for irradiating certain types of cancer in place of the vastly more costly radium.

These uses of radioactive elements have been made under the urge of immediate necessity, even when scientists and medical men are not satisfied with present incomplete knowledge of how they work. To fill in these gaps, physiologists and biophysicists are busy at fundamental researches, using radio-isotopes to obtain better pictures of the reactions in such constituents of living matter as the amino acids, the lecithins, and the nucleoproteins. With a better knowledge of what goes on in living cells, both normal and abnormal, they will be able to attack the problems of cancer and other diseases with much more confidence.

Tree growth in the spring is made largely from the food stored in the bark, stems and roots during the preceding season.

Dye liquors are quickly squeezed out of textiles by whirling the materials at a high rate of speed in a centrifugal machine.

## Isotopes Necessitate Change In Inventory Procedure

# AEC Accounting Methods Revised

► INVENTORY PROBLEMS involving uranium 235, it is suggested by the Sixth Semi-Annual Report of the Atomic Energy Commission, are by no means as simple as those faced by King Midas of the golden touch.

The legendary king, who transformed all his surroundings, including his courtiers and his young daughter, into gold, had only to store his wealth in a vault and keep track of the tonnage on hand.

Present day alchemists have their assay problems infinitely complicated by the fact that they cannot lock up their treasure until they are ready to use it. Their trouble is not in changing one heavy metal into another. That process goes on spontaneously. Their difficulty comes in determining how much of which metal is in any one container at what moment.

Their material is not only in constant state of change, but it is accompanied by radiation in deadly quantities and end-products that are fantastically poisonous. It is often impossible to get close enough to the material to assay it at all.

The Atomic Energy Commission announces in its report completion of the first part of its program to account for stocks of radioactive material in its modernized bookkeeping system. Perpetual inventories of such materials have been established, even though the materials themselves are far from permanent.

If a banker had to keep accounts in a world where gold dollars in his vaults slowly changed into copper pennies, and some of his coins were in liquid and gaseous form, as well as metal, he would understand better the problems of cost accounting among the atoms. The Atomic Energy Commission points out that their accounting system is unique, yet they have succeeded in devising a unified system applicable to all industrial organizations contracting with them on atomic energy research.

Instead of keeping his eye merely on the money coming in and going out of the public treasury, Uncle Sam from now on can tell definitely how much money he will have to save to replace piping for uranium hexafluoride, or what the cost is per milliecurie of invisible radiation.

Modern industrial accounting methods are entering Uncle Sam's bookkeeping system for the first time. Atomic energy and fissionable materials have succeeded in disintegrating the Government's antiquated cash basis accounting. They have replaced it with accrual bookkeeping and cost accounting, so far as the major industrial companies contracting with the Atomic Energy Commission are concerned.

The accounting systems of the Commission and its contractors have been so coordinated that the balance sheet of each company can be entered in the

super-ledgers of the Atomic Energy Commission.

"Taken together," says the Commission in its Sixth Semi-Annual Report, "the books of account kept by

the Commission and its contractors will show the assets, liabilities, net worth, and financial results of operation of the entire atomic energy program."



► "NATURALLY there'll be a little scientific research . . . but the main part of the job is appearing before Congressional committees."

## For The Home Lab

### Urea Synthesis

by BURTON L. HAWK

ONCE UPON A TIME the science of chemistry consisted of two separate divisions: inorganic chemistry — the study of materials derived from the mineral kingdom, and organic chemistry — the study of materials derived from living organisms. Then it was the opinion of leading chemists—including the famous Berzelius—that organic compounds could be formed *only* through the function of a living organism. Therefore the preparation of any organic compound in the laboratory without this "vital force" was absolutely impossible.

But the impossible happened! In 1828, Wöhler heated a solution of ammonium cyanate—an inorganic compound—to dryness. Upon examination of the residue, he found that it contained urea—an *organic* compound! This couldn't be! It was against all theories then in existence! Very doubtful of his results, Wöhler repeated the experiment many times before he finally believed that this transformation actually took place.

"I must tell you," he wrote to Berzelius, "that I can prepare urea without requiring a kidney or an animal, either man or dog."

As happened in the past and probably will happen in the future, the most elaborate theories are crushed by a simple experimental fact.

The preparation of urea by Wöhler was of important historic significance

because it was the first time an organic compound had been prepared synthetically in the laboratory. If Wöhler and Berzelius were amazed at this synthesis, how would they feel if they could view the thousands of compounds made synthetically by the chemist of today!

#### Preparation

You can repeat Wöhler's synthesis of urea in the home lab without too much difficulty. Because of its instability, ammonium cyanate is prepared by mixing solutions of potassium cyanate and ammonium sulfate. Upon evaporation, the ammonium cyanate is converted into urea:  $\text{NH}_4\text{CNO} \rightarrow \text{NH}_2\text{CONH}_2$ , which is obtained as a white powder mixed with potassium sulfate. The urea is extracted with alcohol, in which potassium sulfate is insoluble.

Dissolve 3 grams of potassium cyanate in 15 cc. of water, and add an equal quantity of ammonium sulfate. After all solids are thoroughly dissolved, transfer to an evaporating dish and heat to dryness, stirring frequently. Continue heating until the solid residue is completely dry. Powder the residue with a pestle, then add 5 or 10 cc. of absolute alcohol (either ethyl or methyl). Heat the alcohol to boiling on a steam bath for about 5 minutes; then filter off the undissolved potassium sulfate. Add to this another 5 or 10 cc. of alcohol and repeat the extraction. Combine the two filtrates and cool thoroughly by immersing the container in an ice-salt mixture. Crystals

of urea will separate; filter them off, allow to dry (do not heat).

If potassium cyanate is not available, it can be prepared by the oxidation of potassium cyanide. Dissolve 2 grams of potassium cyanide (**extremely poisonous — handle with great care**) and 2 grams of sodium hydroxide in 35 cc. of water. Thoroughly pulverize 4 grams of potassium permanganate and add to the above solution in small quantities over a period of fifteen minutes. Stir the solution after each addition, but do not allow the temperature to rise above 60°. You might find it more convenient to use a thermometer as a stirring rod. After all the permanganate has been added, heat the mixture in a water bath at about 60° (not over) for about two hours. If necessary, add a small portion of dilute sodium bisulfite solution to use up any unreacted permanganate. Filter off the manganese dioxide, and wash several times with water. The filtrate, which should be colorless, contains potassium cyanate. Add to this 8 grams of ammonium sulfate and evaporate to dryness to obtain the urea as described above.

Urea forms white or colorless crystals soluble in water and alcohol. Upon heating, the aqueous solution gradually decomposes forming ammonia and carbon dioxide.

Urea can also be prepared by heating carbon dioxide and ammonia under pressure or by decomposing calcium cyanamide with dilute sulfuric acid.

It is used in stabilizing explosives, as a fertilizer, in the manufacture of plastics and in the synthesis of pharmaceutical compounds—chiefly barbital and allied products.

Save the urea you have prepared, and proceed to investigate its properties and related compounds.

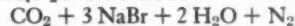
Urea or carbamide,  $\text{CH}_4\text{N}_2\text{O}$ , consists of colorless or white crystals very soluble in water and melting at 132 degrees. It occurs in the blood and tissue fluids and is also present in urine to the extent of approximately 2%. It is excreted from the body as a waste product, or, more technically, as the end product of animal metabolism.

If for some reason you were unable to prepare urea, you can probably purchase a small quantity from the corner drugstore for these experiments.

#### Identification

(1) Dissolve a small quantity of urea in 1 cc. of ethyl alcohol. Dissolve an equal quantity of oxalic acid in an equal volume of ether. Mix the two solutions. The urea separates as a white crystalline precipitate.

(2) If a solution of sodium hypobromite is added to a solution of urea, a violent effervescence takes place with the evolution of nitrogen and carbon dioxide:



If sodium hypobromite is not available, a substitute reagent can be prepared by dissolving equal quantities of salt and potassium bromide in a dilute solution of sodium hypochlorite ("Clorox").

(3) Make a solution of urea alkaline by adding a small quantity of dilute sodium hydroxide. To this solution add a few drops of mercuric chloride solution. A white precipitate forms.

(4) To 5 cc. of a solution of urea, add 5 drops of HCl and 5 drops of formaldehyde. Mix gently. Nothing

will happen at first; however if the solution is allowed to stand for about 10 or 15 minutes, a white precipitate of diformaldehydeurea will suddenly form.

Since it is an amide, urea undergoes hydrolysis when warmed with alkali:



Place about  $\frac{1}{2}$  gram of urea in a test tube. Add 5 cc. of sodium hydroxide solution and heat to boiling. You will soon be able to recognize the odor of ammonia, indicating hydrolysis.

### Biuret

When urea is heated carefully, biuret (allophanic acid amide),



is obtained. This compound is not particularly important. It is best known for its reaction with copper sulfate which is a popular test for proteins (the "biuret reaction").

Place a very small quantity (about 0.2 gm.) of urea in a dry test tube and apply gentle heat. The powder melts to a clear liquid with the production of ammonia. Continue to heat gently. After the ammonia is driven off, the liquid will turn milky and gradually solidify with the formation of biuret. Allow to cool, and add about 1 or 2 cc. of sodium hydroxide solution. Dissolve the solid thoroughly; then add a few drops of dilute copper sulfate solution. A lovely red-purple coloration is obtained. This reaction is characteristic of proteins and polypeptides. As the number of peptide linkages is increased, the color deepens; proteins usually produce a blue violet color.

**Urea Nitrate**—To a concentrated solution of urea, add a few drops of nitric acid. Immediately a crystalline

precipitate is formed which settles quickly to the bottom of the tube. Urea nitrate will dissolve in an excess of water.

**Urea Oxalate**—Proceed as above using concentrated oxalic acid solution instead of nitric acid. Crystals of urea oxalate will separate out and fall through the liquid like a miniature snowstorm. This compound will also dissolve in excess of water.

Other compounds formed similarly are urea hydrochloride and urea phosphate. Urea also forms a number of additional compounds with inorganic salts, but they are not important.

### Uses

Urea forms thermosetting resins with formaldehyde, similar to the phenol-formaldehyde type. They are sold under the trade names of "Beetleware" and "Plaskon."

Dissolve 1 gram of urea in 8 cc. of water; add 2 cc. of hydrochloric acid and 2 cc. of formaldehyde. Shake thoroughly and allow to stand. The mixture will turn white and gradually harden.

New uses are still being found for urea—the first organic compound ever prepared synthetically. Perhaps you have read about the new anti-decay tooth powder. Scientists have reported that brushing the teeth with a mixture of urea and dibasic ammonium phosphate is useful for the prevention of decay. It is the same product you have been experimenting with, but in toothpaste urea is marketed under its chemical name, carbamide. Thus a waste product of nature is used to prevent waste in the form of tooth decay!

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MISTRY

## Plastic Instead of Gelatin Foreseen in Photographic Film

### Synthetic For Photo Emulsion

► OLD-FASHIONED gelatin, made from skin of calves, may in the future give way to a synthetic plastic as the emulsion that coats photographic film and carries the chemicals that are affected by light and make the picture.

The replacement of conventional gelatin by a synthetic polymer resin in a duPont color printing film suggests that synthetic material may eventually be used in more photographic films.

Color film emulsions using gelatin have a chemical put into them which makes the dyes stick to the silver image, called a color former. The new film uses the synthetic polymer to replace both the color former and the gelatin binder, thus making the one substance do the work of two.

Because the new color former plastic is only swollen by water, the dyes in the resulting picture are deposited in place and keep the picture sharper than by the older method.

The new color film announced by duPont is for professional 35 mm mo-

tion picture projection. The film consists of three emulsion layers superimposed on one side of standard cine film base. Each layer contains the sensitive silver salts suspended in the new color former plastic.

In each emulsion the amount of dye in the final print is proportional to the amount of silver deposited by the first exposure and development.

The gelatin now in use for photographic films is made from the skin of calves. The quality and impurities of gelatin have a great effect on the sensitivity of the photographic emulsion. The plants that the animals eat affect the gelatin made from their skin. Two drops of mustard oil per ton of emulsion is enough to increase the sensitivity of a gelatin emulsion.

The synthetic resin can be made under controlled conditions and should be more uniform. The physical characteristics of some of the synthetic plastics may be better than that of gelatin. They may have better dimensional stability.

### Radioactive Carbon For Ice Age Dates

► RADIOACTIVE carbon in bones, shells and wood left behind by animals and plants that died during the latter part of the Pleistocene ice age may help materially in dating geologic events of 35,000 years ago. Prof. Richard Foster

Flint, Yale University geologist, has invited colleagues who have materials of this kind to send him exact descriptions, with a view to later analysis to determine their age.

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## Low Temperature Rubber Has Longer Life

# "Cold Rubber" is a Process

by A. C. MONAHAN

► "COLD RUBBER" is cold in name only. It is produced at near-freezing temperatures, instead of at the heat of the Mohave desert in summer as the usual synthetic rubbers are, and from this it gets the title. Long life in service is its superiority.

This new synthetic rubber is already in wide use throughout the United States in the tread on automobile tires but will be much more widely used when it becomes available in quantities.

It is also under test in footwear, and other applications are foreseen. Manufacturers claim that the tire with a cold rubber tread will outwear one with a rolling surface of natural rubber.

This man-made superior rubber for tire treads, and the earlier superior rubber for tire tubes, will not put the natural rubber plantation out of business. There are plenty of uses for the natural products, and more in the making, and then there is the question of economics in the production and the use of the two. One very important point, however, is worthy of note. In times of emergency, the United States is now independent of foreign rubber.

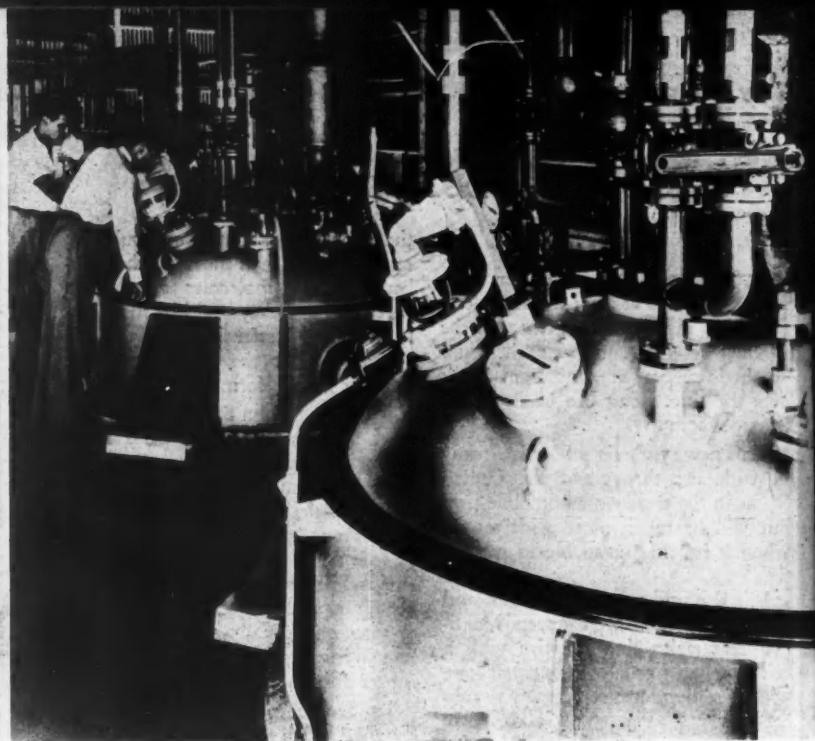
Cold rubber is made from the same materials as the Buna S (GR-S) synthetic, one of the most widely used types of man-made rubber. Key to the superiority of the new product lies in

the accepted idea that its molecules are more uniform than those in other rubbers. Rubber molecules are like a barbed wire if they could be sufficiently magnified, a scientist recently stated. In cold rubber the barbs would be more or less uniform.

In making Buna S rubber, the standard ingredients are 70 parts butadiene, derived from either petroleum or alcohol, and 30 parts styrene, chiefly a coal derivative. When the mixture is put into a container, the top layer is made up of these two ingredients, while below is a layer of water containing a dissolved emulsifier, such as soap, and usually a dissolved catalyst. When the mixture is stirred, the rubber forms.

The butadiene and styrene are polymerized together, a scientist would say. In polymerization, big molecules are made out of little ones. Under usual methods, the rubber formation takes place at a temperature of 122 degrees Fahrenheit, and the process requires from 12 to 14 hours. In making cold rubber, a temperature near the freezing point of water is used, and the process requires much less time.

In the production of cold rubber, an organic peroxide is used as a catalyst instead of the inorganic salts usually employed. One such cold-rubber catalyst is cumene hydroperoxide. This organic peroxide was worked out in the University of Minnesota laboratories under the direction of Dr. I. M. Kolt-



► GIANT REACTORS in the Copolymer plant operate somewhat like old-fashioned ice cream freezers mixing the ingredients for cold rubber.

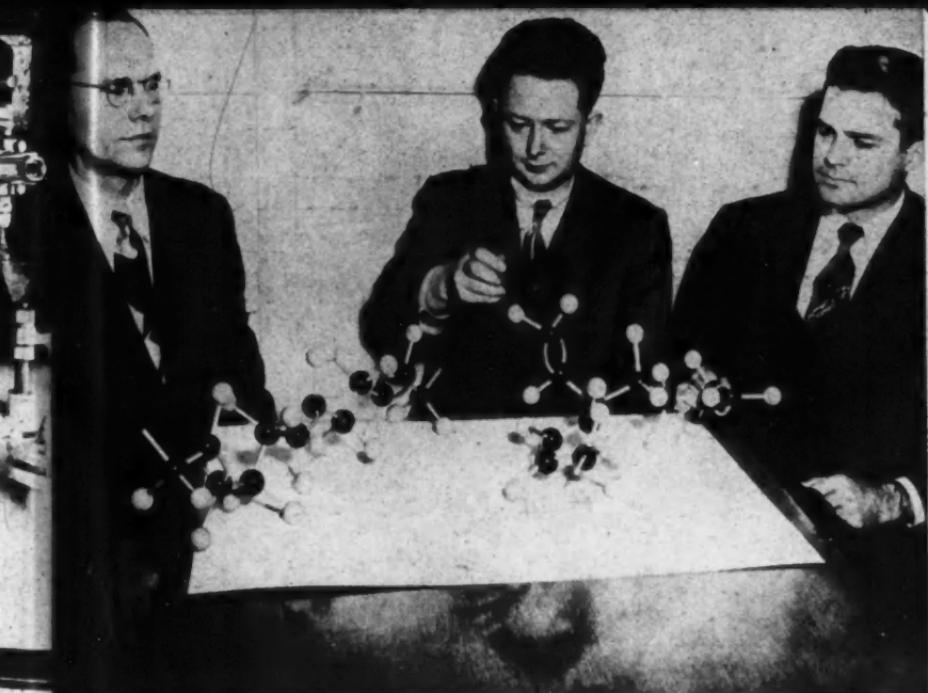
hoff, and is a key ingredient in the low-temperature process.

In compounding the synthetic rubber into vulcanized products, such as tires, a new kind of carbon black, finely divided carbon filler for the rubber, is contributing greatly to the quality and economy of the product. This HAF, or furnace black as it is called, is made from oil or enriched natural gas.

The development of cold rubber was not a one-man job. Experimental work was carried out in several university

laboratories, notably at the University of Minnesota, and in laboratories of the rubber industry. Most of the rubber companies contributed to the development.

While laboratory quantities had been made earlier, the first pilot plant production was made by the Phillips Petroleum Company in the late spring of 1946. Shortly after the middle of the same year, Goodyear Rubber Company produced a ton for experimental purposes. The U.S. Rubber Company made the first plant scale run of low



► COLD RUBBER has straight-line molecules illustrated by the model on the left, while on the right these United States Rubber Co. scientists show how hit-or-miss chains form natural rubber.

temperature rubber in the summer of 1947. Copolymer Corporation, Baton Rouge, after pilot plant operation the same year, converted half of its 30,000-ton capacity to 41-degree rubber during 1948. Some six or eight companies are now making cold rubber.

The conversion of a plant from ordinary Buna S to the cold rubber type is not a difficult or costly job. The installation of refrigerating equipment is necessary. Also required are tanks, compressors and other machinery for working at the lower temperatures. Over half of the operating capacity of the government-owned rubber plants,

actually operated by private companies, has now been converted or is in the process of conversion to produce cold rubber.

Glowing reports of the superior qualities of cold rubber hastened the rush to its production. Synthetic rubber is now at least as good as the natural product, and most of the reports credit it with being better. A prediction that 75,000-mile automobile tires will be available soon was made recently by a rubber scientist. The cold rubber tire does not heat up at traveling speed any more than the natural rubber sort. The older synthetic tires



► COAGULATED LATEX of cold rubber is ready for processing after it is washed free of chemicals that helped its formation.

co. The claim is made that it is 100% better than regular synthetic in tread cracking resistance, develops 15% less heat when flexed, bounces 10% better, and is from 20% to 30% stronger.

Cold rubber is, like GR-S, unsuitable for heavy truck tires, which because of their bulk dissipate heat slowly, scientists of the Firestone Tire and Rubber Company, Akron, Ohio, recently reported.

As to skidding, cold rubber behaves relatively well on wet roads, but is inferior to natural rubber on ice or snow, they said. Preliminary tests on cold rubber in treads show that it is approximately equal to GR-S for traction around the freezing point, but is inferior in the lower and less critical temperature ranges, such as zero degrees Fahrenheit.

In cost, cold rubber will be about the same as other synthetic rubber. C. M. Hulings, of the Copolymer Corporation, recently said, "Since somewhere near 85% of the cost of producing cold rubber lies in its raw materials, a prediction of the future costs must necessarily depend upon what raw materials are to be used, and what the prices of these raw materials are going to be. This I can not predict, but I can say that the present-day cost of cold rubber is almost exactly that of the regular synthetic rubber we have been making."

Copolymer Corporation is unique in its organization. It was established in 1942 by seven of the so-called medium-sized tire companies, whose combined size and consumption of rubber would be reasonably comparable to a single one of the larger companies. Its neutral name "Copolymer"

represents the rubber process of co-polymerization, being a combination of two chemicals or polymers. It has a representative on its board of directors of each of the constituent companies.

"While the full-scale production of 41 F cold rubber is a mile-stone of the greatest significance to the American rubber industry, scientists and rubber technologists by no means consider this the completion of their tasks," Dr. W. B. Reynolds of the Phillips Petroleum Company recently stated. "Already even more exciting products and processes are clamoring for recognition. In particular, new synthetic rubbers produced at still lower temperatures possess properties suggesting commercial utility. Such 'antifreeze' polymers have shown almost unbelievable wearing qualities in tire treads and their properties strongly suggest wide-scale future use in tire carcasses."

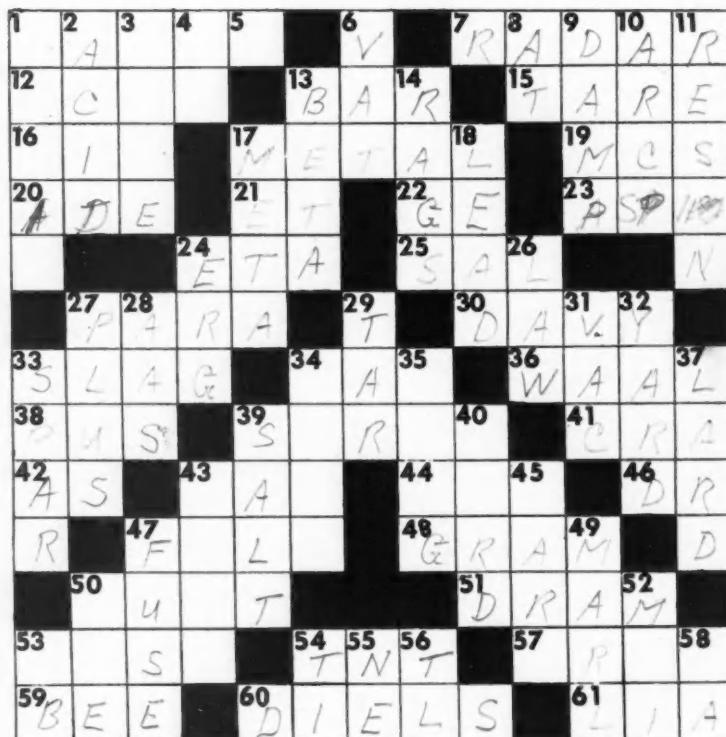
One of the factors responsible for the final rapid development of cold rubber was the development of the so-called MDN-ferricyanide system, according to Dr. Reynolds. MDN, a "speed-up" chemical from a class known as diazo thio ethers, was introduced into polymerization work at the University of Cincinnati. Chemists at the University of Minnesota discovered that this new chemical, when combined with ferricyanide, gave unusually fast polymerizations even at low temperatures.

Both the Cincinnati and Minnesota work was sponsored by the federal Office of Rubber Reserve. The government laboratories operated for Rubber Reserve by the University of Akron carried the MDN-ferricyanide recipe to small pilot plant scale.

## Chem Quiz

### Chemical Crossword Puzzle

by LLOYD FERGUSON



#### HORIZONTAL

1. The melt of the sulfides of iron and copper formed in the smelting of copper.
12. Organic radical attached by a carbonyl carbon atom.
13. Ingot.
15. Weight of the container.
16. Rounded edge of a vessel.
17. A substance whose oxide combines with water to form a base.

#### VERTICAL

1. A dicarboxylic acid chiefly obtained from apples.
2. The conjugate of a base.
3. A class or group.
4. Element of the aluminum family commonly found in ant and rat poisons (abbr.).
6. A large receptacle used for carrying out batch operations.
8. Atomic (abbr.).

## *World's First Molecular Disease*

► DISEASE has been traced to a difference in the composition of a chemical molecule of the blood and the charge of electricity upon it.

Dr. Linus Pauling, of the California Institute of Technology, has reported to the National Academy of

Sciences that sickle cell anemia seems to be the world's first molecular disease. This disorder has red blood cells that have the shape of a sickle, and this is caused by the difference in the two kinds of hemoglobin molecules.

## Cross Word Clues Continued

### HORIZONTAL

19. Montreal Chemical Society (abbr.).
20. Suffix denoting salt of a binary acid.
21. In addition to (Fr.).
22. Element of family B, Group IV in the periodic table, formerly called eka-silicon by Mendeleeff.
23. Unit of pressure.
24. Seventh carbon atom from the carboxyl group in the side chain of a fatty acid.
25. Salt.
26. Opposite carbon atoms of the benzene nucleus.
27. English chemist, first to isolate sodium and potassium and inventor of the miners' safety lamp.
28. Molten mass formed to carry away impurities in the metallurgy of iron.
29. A fatty-acid ester of glycerine.
30. Physical chemist after whom certain intermolecular forces are named.
31. A viscid secretion from inflamed tissues.
32. A plastic tubing especially resistant to chemicals.
33. Chemical Research Association (abbr.).
34. Element found in organo-metallic drugs for the treatment of syphilis (symbol).
35. A resinous substance used in making varnishes.
36. Short fibers.
37. Dram (abbr.).
38. One gram molecular weight.
39. Common unit of weight.
40. Early stage in the decomposition of vegetable matter under the influence of extreme pressure and temperature.
41. A "shot" of spirits; also a unit of weight.
42. An aromatic, resinous exudation from trees and shrubs.
43. A popular high explosive (abbr.).
44. An aromatic organic radical.
45. An insect from which formic acid is notably obtained by its distillation.
46. Senior author of a condensation reaction between alkenes and 1,3-dialkadienes.
47. Literate in Arts (abbr.).

### VERTICAL

9. Slightly moistened with a liquid.
10. Electrical discharge between two electrodes.
11. Organic amorphous solid, or semi-solid, formed by polymerization.
12. Position of the —OH group in hydroxymonocarboxylic acids which lose water upon pyrolysis.
13. Fragments used as raw material in the paper industry.
14. The phosphoric acid which is also called glacial.
15. A metallic element used for shields from harmful, penetrating radiations.
24. A unit of energy.
25. Positive sign.
26. American Association of Scientists (abbr.).
27. Thick, black, viscous organic matter.
28. Void of matter (colloq.).
29. English unit of length.
30. A vitreous, crystalline, lustrous mineral.
31. Facet.
32. A penetrating, disagreeable taste.
33. The white semisolid oil of hogs' fat after rendering.
34. The product of an acid reacting with a base.
35. An oil from a spikenard formerly used in medicine.
36. A mixture of sand and clay containing organic matter.
37. A high grade natural rubber named after its location of cultivation.
38. A transition from the solid to the liquid state.
39. A crystalline mixture of limestone and clay.
40. A metallic, wide, shallow vessel.
41. Myrialiter (abbr.).
42. Element found in the mineral ore barite (symbol).
43. Element of family A, group IV, 3rd period of the periodic table (symbol).
44. Inert element whose name means "new" (symbol).
45. Element whose name is derived from the Greek word, thallos, for "budding twig" (symbol).
46. Lightest of the rare earth elements (symbol).

Answer on page 48

**Many Chemical Classes  
Yield Fast Dyes**

## The Art of Coloring

by RAY Q. BREWSTER

*From a new book, Organic Chemistry, published by Prentice-Hall, \$6.*

► THE ART of coloring cloth, leather, or other materials in such a way that the color is permanent and appears to be an integral part of the fabric rather than a paint applied to the surface is the function of the dye industry. In ancient times, the materials used to produce these colors were few in number and were obtained from vegetable or animal sources. As early as 3000 B.C. the Egyptians were using indigo, which occurs as a glycoside in the leaf of the indigo plant. Alizarin, another very ancient coloring material, is found in the root of the madder plant; and, although it has only a poor coloring power of itself, it gives various shades of red and blue with metallic salts. Scarlet-colored cloth was produced in antiquity by dipping the cloth first in a solution of alum or lime water and then boiling the cloth with an extract of the madder root. The "Tyrian" purple was obtained from a small snail (*Murex bandaris*) found near Tyre and was so costly that it was available only to those of high estate, hence its name "royal" purple. These and a few other natural products constituted the dyeing materials of ancient times; and, with but few additions, they continued in use until the rise of the modern synthetic dye industry during the latter part of the nineteenth

century. The story goes that Abraham Lincoln cut and split a quantity of rails in payment for a homespun suit of clothes dyed with the brown coloring matter of walnut bark. Even in that comparatively recent period of the world's history, the art of dyeing cloth had progressed but little from its ancient state.

The first coal-tar dye (*mauve*) was discovered by Sir William Perkin in 1856 by the oxidation of a mixture of aniline, *o*-toluidine, and *p*-toluidine. At the present time, indigo, alizarin, Tyrian purple (6, 6' dibromoindigo), and many hundreds of other dyes are produced synthetically and at little expense from substances obtained from coal tar. Hence, they are called "coal-tar dyes" or "aniline dyes," although many of them have no direct connection with aniline itself.

Azo dyes of a wide range of colors are made easily, and many of them are quite stable (fast) to light and laundering. Hence, they comprise one of the most important classes of coloring materials . . . Methyl Orange imparts an orange color to wool and silk, but it has little usefulness as a dye because it is not fast to either sunlight or laundering . . . Congo Red was the first dye discovered (1883) that is a direct (substantive) dye for cotton. This property of dyeing cotton without a mordant

gives Congo Red and related dyes great importance. It is manufactured in large quantities by *tetrazotizing* benzidine and coupling with naphthionic acid. In the laboratory Congo Red is used as an indicator. Its color change is just the opposite of litmus—red in alkali, blue in acid. . . .

### Triphenylmethane Dyes

Malachite green gets its name from the fact that its blue-green color resembles that of the copper ore malachite, which consists principally of basic copper carbonate. It imparts a beautiful blue-green color to wool and silk, but for application to cotton, it requires a mordant of tannic acid. . . . Fuchsine dyes wool and silk a rose-red color but requires a mordant (usually tannic acid) for application to cotton. . . . Crystal Violet, hexamethylpararosaniline, may be prepared by methods comparable to those used for the manufacture of Malachite Green. Crystal Violet is an excellent dye for wool and silk but, like Malachite green and fuchsine, requires mordants when used with cotton. Methyl Violet, pentamethyl rosaniline, also known as "Gentian Violet," is similar to Crystal Violet, but has one less methyl radical. Both dyes are used as biological stains. . . .

### The phthaleins

Dyes of the phthalein type are derived from phthalic anhydride in the presence of sulfuric acid or zinc chloride. Phenolphthalein is important as an indicator, but it is of no value as a dye. It is used in medicine as a laxative. . . . Fluorescein is an orange powder which dissolves in alkaline solution producing a strong green fluorescence. The alkaline solution ap-

pears yellow by transmitted light and green by reflected light.

Mercuration of dibromofluorescein leads to the production of the well-known antiseptic mercurochrome. The bromination may be accomplished conveniently in acetic acid solution. For mercuration, the dibromofluorescein is heated first with mercuric acetate and then with sodium hydroxide solution.

### Alizarin

Alizarin occurs as the glucoside, ruberythric acid, in the root of the madder plant (*Rubia tinctorum*). Alizarin was known and employed by the ancients and was prepared exclusively from plant sources until recent times. . . . Although Alizarin itself has a yellow color, it is a poor dye. However, it forms brilliant lakes with salts of aluminum, calcium, iron, and other metals. Cloth mordanted with aluminum, calcium, and tin salts develops a red color with alizarin. Iron mordants give a dark violet lake, and chromium salts produce a red-brown shade.

### Indigo Vat Dye

Vat dyes are insoluble colored compounds which yield soluble products upon reduction. The reduction products may be either colored or colorless and have a distinct affinity for textile fibers. In applying a vat dye to the fabric, the dye must be reduced with sodium hyposulfite ( $\text{Na}_2\text{S}_2\text{O}_4$ ), or other suitable reducing agent, in a tank out of contact with the air. The fabric is then impregnated with the soluble leuco form of the dye. Upon exposure to the air or other oxidizing agent, the colored

insoluble dye is regained and remains firmly fixed in the fiber.

Indigo is the classic example of a vat dye and is the oldest dyestuff known. The cloth in the pyramids of Egypt is dyed with it. The indigo plant, however, does not contain indigo itself, but a colorless glucoside known as "indican" which upon hydrolysis yields glucose and natural indigo. The plants are cut early in the

morning and placed with water in large "steeping vats" where a vigorous fermentation reaction brings about the hydrolysis of indican to a solution of indoxyl and glucose. This solution is drawn off and thoroughly oxidized by air for the conversion of indoxyl to indigo. The precipitate of blue indigo powder is removed by filtration, washed with water, pressed into molds, and dried.

## *Compound 42 is New Rodenticide*

► A NEW RAT-KILLING chemical, that does rodents to death by causing internal bleeding, has proved up well in field tests conducted by the U.S. Fish and Wildlife Service at the University of Florida. The 100% kill obtained earlier under laboratory conditions has been practically duplicated in the larger-scale tryouts.

The new compound, at present known simply as Compound 42, is a chemical relative of dicoumarol, the substance found in spoiled sweet clover that prevents the clotting of blood. It has a similar physiological effect, and thus starts and maintains fatal bleeding in the rats' abdominal areas.

Compound 42 does not kill at a single dose, as most other rodenticides do; four or five successive feedings are required. However, the effect is cumulative, and once a rat has eaten enough of it he is a "goner." Rats do not learn to avoid it, nor do they develop any tolerance.

Most effective mixture was found to be 46 grams—slightly more than one and one-half ounces—in 100 pounds of solid food. Four or five feedings of this mixture, over as much as a 12- to

15-day period, produced a practically total kill.

Field tests were made on both the common brown rat and the scarcer black rat. The black rat, though a smaller species, had four times the resistance of the brown rat, but the recommended mixture was sufficient to kill both species. Mr. Spencer is now testing Compound 42 on the house mouse.

Unlike the highly dangerous poison known as 1080, used in professional rat-eradication programs, Compound 42 is not harmful to larger animals or to human beings in the dosage recommended for rodents. Moreover, whereas 1080 has no antidote, the action of Compound 42, if accidentally swallowed in dangerous quantity, can be checked. This can be accomplished either by blood transfusion or by the administration of clot-promoting vitamin K.

Compound 42 was first isolated in 1943, in a search for anti-coagulant derivatives of dicoumarol. Shelved for five years, it was again picked up in 1948 and subjected to extensive laboratory tests to determine its value as a rodenticide.

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## Bright-Line Spectrum Is Message From Atom

# What We Know About The Atom

by HELEN M. DAVIS

► SMALL AS the dimensions of the atom are, and hopeless as we may be of ever getting as much direct information as we would like about this limiting particle, nevertheless, the atom is real. We get exact data from the atom itself. We can read the values of the data with our own eyes. If instruments are needed to evaluate the data, they are in many cases so simple that they can be made by any amateur who has the average amount of skill with tools plus the interest to stick to his project until he achieves results.

CHEMISTRY offers, beginning in this issue, a series describing instruments you can build, from directions written by the men who invented them, with which you can experience atomic phenomena. The first of these descriptions follows this introductory article.

First, let's get some atomic history straight.

When the Greeks coined the word atom, they were indulging in philosophical argument. Two possibilities present themselves, their reasoning ran. Either a substance is capable of infinite division, or it is not. If it is not, somewhere there must exist a particle which, for some reason, is incapable of further cleavage. They had no experience of any such particle, so they coined a name to fit the idea: *a-tom, can't-be-cut*. The word is the sole contribution of Greek science to modern atomic knowledge.

During the next two thousand years a great deal of information on many subjects was accumulated by many people, but little occasion was found for taking up the Greeks' argument about ultimate indivisibility. Many substances were classified, some new ones were discovered, a number were analyzed into simpler substances. Very gradually men learned that making gold out of salt, sulfur and mercury is nothing like as important as learning what gold, salt, sulfur and mercury really are.

After the nature of elements and compounds began to be understood, a remarkable fact appeared, which revived interest in the hypothetical atom. Whenever two or more elements combine to form a compound, definite and constant amounts of each take part in the reaction. Moreover, when the same elements combine in different ratios to make a series of compounds, a definite and simple numerical relationship exists between the amounts, so that we can say that one part of one element combines with twice as much of another, when we base the comparison on the weights of the combining quantities. It is easy to explain this relationship in terms of atoms. One atom of the first combines with two atoms of the second.

John Dalton, (1766-1844), the man who first described color-blindness, formulated the modern idea of the

atom, and suggested the use of chemical formulas. His scheme used circles and other geometric figures to represent the different atoms. It was reserved for later chemists to simplify the symbols to letters and abbreviations for the names of the elements, and numbers to show their duplication.

Dalton, however, knew no more about the nature of the atom than did the Greeks. He took the side of the argument which believed in indivisible unit quantities of matter, because he felt that such units best explain the observed facts of combining ratios. The atom itself had yet to make its presence known.

Sir Humphrey Davy, in 1808, was trying out his voltaic cells on as many earthy-looking compounds as he could find, with the object of discovering metals in them. He noted among other observations of strontium chloride, "when brought in contact with the flame of wax, tallow, oil, or alcohol, it tinged it of a rose colour; and this is a distinctive character of the compounds of strontium; the salts formed from it give this tint to flame, those of baryta give a yellow tint."

We do not know how many other people had noticed the flame colors characteristic of these rare compounds. Those who did were receiving atomic messages. Half a century after Davy's discoveries, Robert von Bunsen and Gustav Kirchhoff learned how to read them.

"It is well known," they wrote in 1860, "that many substances have the property when they are brought into a flame of producing in the spectrum certain bright lines. We can find

on these lines a method of qualitative analysis which greatly enlarges the field of chemical reactions and leads to the solution of problems, unsolved heretofore."

The famous team of experimenters began, as will the amateur today, with the colors shown by salts of the alkali and alkaline earth metals. They were careful to purify the compounds they studied by repeated recrystallization. They made use of ammonium carbonate to precipitate the salts they wanted, and they recrystallized from alcohol wherever practical. These reagents avoided contamination with substances that would confuse the spectrum lines. The scientists soon found that certain bright lines always appeared for each metal no matter which salt of that metal they used.

"The lines referred to show themselves the more plainly, the higher the temperature and the weaker the natural illuminating power of the flame. The gas lamp described by one of us," they said "gives a flame of very high temperature and very small luminosity; this is consequently especially adapted to investigations on those substances characterized by bright lines."

Flame colors, like the red of strontium or the blue and green of copper, originate in the atom. This is one of the direct bits of evidence we have about this mysterious entity, and study of such light brings out a surprising amount of information about the region from which it comes. This is direct, factual observation.

While the distinctive red color is confirmation that the element strontium is present, and other colors are

characteristic of several other elements, the message from the atom, as read through the spectroscope, has much more information to impart. The bright lines form a puzzling pattern with no obvious regularity. Some elements show very few lines in their spectra, others show many. Iron is noted for its enormous number throughout the range of visible light and beyond. Some lines are wide and some are thin. Some occur in pairs or groups of the same color. Some appear under certain conditions and not under others. Scientists were soon at work mapping the bright-line spectrum and measuring the wavelengths of the colors.

The accompanying cut and description tell how Bunsen and Kirchhoff built the first spectroscope. With it they recognized the bright lines characteristic of metallic elements whose salts are vaporized in the Bunsen burner flame. You can build an instrument like theirs and observe

these messages from the atoms of such elements.

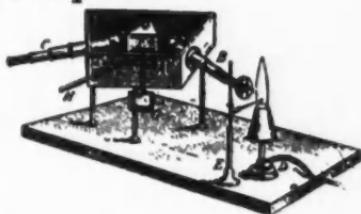
Suggestions that might be made for modern spectrosopes include substitution of a glass  $60^\circ$  prism for the one Bunsen and Kirchhoff made with three plates of glass cemented together and filled with carbon disulfide. The  $45^\circ$  prisms available from Army surplus can be used, but do not give as satisfactory a spectrum as those of  $60^\circ$ . Two new razor-blades may be used for the "cheeks" of the slit. The small telescopes may be purchased from instrument makers, or constructed from lenses and tubing. Bunsen's is still the most satisfactory burner for producing a colorless flame.

By replacing the eye-piece of telescope *C* with a camera, you can photograph the spectrum, and make an enlarged print for detailed study. Later articles in this series will explain how the bright-line spectra have been measured and mapped.

## The Spectroscope

► CHEMICAL ANALYSIS BY SPECTRAL OBSERVATIONS, by G. Kirchhoff and R. Bunsen. *Poggendorf's Annalen*, Band 110, 1860. Translated by D. B. Brace, published in *The Laws of Radiation and Absorption*, New York, 1901.

► THE FIGURE represents the apparatus which we have used mainly in the observation of the spectra. *A* is a box blackened on the inside, the bottom of which has the form of a trapezium and rests on three feet; the two inclined sides of the same form an angle with one another of about  $58^\circ$  and carry the two small telescopes *B*



and *C*. The ocular of the first is removed and replaced by a plate in which is a slit formed of two brass cheeks which are placed at the focus of the objective. The lamp *D* is so placed before the slit that the mantle of the flame is intersected by the axis

of the tube *B*. Somewhat beneath the point where the axis meets the mantle the end of a very fine platinum wire, bent into a small hook and carried by the holder *E*, passes into the same; on this hook is melted a globule of the chloride previously dried. Between the objectives of the telescopes *B* and *C* is placed a hollow prism *F* with a reflecting angle of  $60^\circ$  and filled with carbon disulfide. The prism rests on a glass plate which can be rotated on a vertical axis. This axis carries on its lower end the mirror *G* and above it the arm *H* which serves as the handle to rotate the prism and the mirror.

A small telescope is adjusted before the mirror which gives an image of a horizontal scale placed at a short distance. By rotating the prism we can cause to pass before the vertical thread of the telescope *C* the entire spectrum of the flame and bring every portion of the spectrum into coincidence with this thread. To every reading made on the scale there corresponds a particular portion of the spectrum. If the spectrum is very weak the cross hair of the telescope *C* is illuminated by means of a lens which throws some of the rays from a lamp through a small opening which is placed laterally in the ocular of telescope *C*.

## *Synthetic Detergents Foul the Works*

► SYNTHETIC detergents may be a boon to the housewife, but they are also under suspicion from chemists for fouling up the works—water works and sewage disposal works.

As the only new factor known, the soapless soaps are suspected of being to blame for settling tanks not settling.

Circumstantial evidence against the synthetic detergents is the fact that the recent settling tank trouble seems to come early in the week. Monday washings with the new products look like a good bet for the blame.

William Gallagher, superintendent of the Appleton, Wis., Water Department, calculated the amount of detergents causing the difficulty at his plant on the order of one part per million.

No fungicide is known that arrests fungi in their early stages and prevents them from forming colonies, and is also non-corrosive, non-toxic to humans, permanent and colorless.

Lindsey Hobbs of the Standard Oil Company (Ind.) indicated that this would make it hard to get proof in blaming the new cleaners. He said that present techniques give only questionable results at concentrations as high as 200 parts per million.

Detergents in the water in very small amounts give an undesirable flavor ranging from soapy to bitter. And they can produce "off-odors" in tests described by J. T. Cross of the Chicago Water Department.

Conclusions of the chemists, reported in Chemical and Engineering News, were that methods of analyzing for smaller quantities should be developed and ways of decomposing the compounds needed to be found.

## How to Protect Metals Other Than Through Coatings

# Metal Corrosion Problems

► THE POOLING of knowledge on metal corrosion and its prevention, gained from scientific research by many men in various parts of the world, is responsible for modern methods now widely applied to give metals in use longer life. F. L. LaQue of the International Nickel Company, New York, at the United Nations Scientific Conference on the Conservation and Utilization of Resources, reviewed the most effective means of preventing corrosion, other than the use of protective coatings such as grease, paint and zinc. These include humidity control, de-aeration, the use of inhibitors, cathodic protection, design and the use of alloying materials.

Since practically all common corrosion processes require the presence of water, or water vapor, it is possible to prevent corrosion by eliminating water. It has been established that when the relative humidity is kept below 30% corrosion will be negligible. The control of humidity in large spaces can be accomplished by the use of air-conditioning equipment. With packaged apparatus, the air within can be kept dry with the use of a suitable moisture-absorbing substance such as silica gel. When the package is a metal container, the inside air can be replaced with an inert gas such as nitrogen.

De-aeration, or deaeration, includes the removal of atmospheric or other oxygen from the environment. Oxygen plays a part in much corrosion. An

example of the application of this process is in the use of a deaerator in the treatment of boiler feed water. It is possible to reduce the oxygen content of water below 0.01 part per million. Deaeration has also been applied successfully to the prevention of corrosion of steel pipe lines used to carry otherwise corrosive water for long distances.

Inhibitors are compounds that stifle either the anodic or cathodic portions of the normal corrosion reactions, or both. Most inhibitors function as chemically or physically absorbed films which either alter the electrochemical characteristics of the metal, or serve as mechanical barriers to the normal corrosion processes.

Cathodic protection, first used in 1824 by Sir Humphrey Davy, is one of the most effective means of preventing or arresting corrosion. It is based on the principle that most corrosion of practical importance is electrochemical in nature and results from the flow of current through an electrolyte between areas of different potential which may exist on the surface of a single metal or between two or more different metals. The solution is to bring all surfaces to the same potential.

This can be accomplished in most cases by introducing a current to offset the one produced by the difference in potential. In Mr. LaQue's language, "by discharging current on the more noble (cathodic) surfaces so as to achieve their cathodic polarization to the potential of the adjacent anodes."

By far the most important application of cathodic protection has been in connection with the thousands of miles of underground oil, gas and water pipe lines, and power and communication cables.

Good design for metal structures avoids crevices favorable to corrosive action, or to galvanic action that could cause corrosion. It is bad practice, according to Mr. LaQue, to use threaded connections between dissimilar metals; brazed or welded joints are much better.

One of the most effective means of increasing the durability of the elemental metals is to combine them in alloys or to control their minor constituents so as to achieve the corrosion-resisting properties desired. Stainless steel is the most spectacular example. Iron alloyed with chromium and nickel, sometimes supplemented with molybdenum, columbium, titanium, silicon, copper or tungsten added for specific purposes, may have its ability to resist corrosion increased 100,000 times that of ordinary iron.

## *Isotopes From Cyclotrons*

► RADIOACTIVE isotopes will be produced in cyclotrons under the U. S. Atomic Energy Commission program.

For three years, these important tools of modern science have been produced in the chain-reacting atomic furnace at Oak Ridge, Tenn. and shipped to scientists. Use of cyclotrons will give a wider variety of isotopes than is possible with the pile.

The Carbide and Carbon Chemicals Corporation is authorized to purchase cyclotron time for making isotopes from institutions which have these atom-smashers. Institutions which will be utilized include the Massachusetts Institute of Technology, University of Pittsburgh, Washington University, and the Crocker Radiation Laboratory at the University of California. Assistance to the general program will be rendered by the department of terrestrial magnetism of the Carnegie Institution of Washington.

Some of the elements and their atomic weights which will be available to scientists for the cyclotron production include: beryllium 7; sodium 22; iron 59; iron 55; zinc 65; arsenic 63; and iodine 125. Only isotopes with a half-life longer than 30 days will be shipped at first. The half-life is the length of time in which the radioactivity of the isotope is diminished by half.

The new cyclotron-isotope program was strongly urged by the National Research Council. Cost of the newly-available isotopes is higher than the pile-produced ones. The AEC is therefore a subsidized program. As with the pile isotopes, distribution will be made free of charge for cancer research.

Because cyclotrons are available in many countries abroad, the new program will be limited to the United States and its territories and possessions.

## Oxygen and Fuel Dangerous When Combined in Same Molecule

# Big Blow-Ups

*Reprinted from the Industrial Bulletin of Arthur D. Little, Inc.*

► PEACETIME research following developments in World War II has led to a better understanding of the behavior of high explosives, how they may be controlled for useful applications, and how accidents may be prevented. While the basic chemistry of highly explosive materials has been well understood for years, spectacular explosions, such as that at Texas City, indicate the need for more detailed knowledge of the conditions which can lead to explosions and for wider application of known safety procedures.

Chemical or combustion explosions, as distinct from explosions caused by overloading pressure vessels, always involve rapid rise in temperature. In one type, probably the most common, finely divided combustible material is dispersed throughout the air as dust or vapor. If conditions are right, and the dust is ignited, the explosive reaction proceeds throughout the mass or cloud with the speed of sound. If cornstarch is suspended in the air at a ratio of a seventh of an ounce to a cubic foot of air, and the mixture is ignited under proper conditions, the resulting explosion would have enough power to wreck a substantial building.

In true explosives, there is no need for atmospheric oxygen, for oxygen loosely bound within the molecule of the explosive can, with proper stimu-

lation, combine with carbon and hydrogen also present in the molecule. While a dust explosion pushes away objects in its path, detonation of a true high explosive shatters or penetrates the opposition. The "shock waves" which distinguish a high explosive from straightforward combustion generate pressures estimated as high as 100,000 atmospheres, or one and a half million pounds per square inch. Temperatures may go as high as 7000°F. Impingement of the shock wave on an obstacle is the cause of the damage. Damage may result also from the "kick-back" or reaction at the site of the explosion, due to the inertia of an air mass in the path of expansion or a water mass behind the charge.

The typical high explosive builds up a maximum pressure rapidly, with a total duration measured in millionths of a second; the intensity of the dust type is less, but the duration of the pressure is longer. Although serious results can occur when an explosive reaction takes place between finely divided particles and air in a confined space, the conditions can be recognized and accidents avoided. In handling high explosives, however, the oxygen and its fuel cannot be separated, since they are in the same molecule; danger is always present and occasional spontaneous detonation is unavoidable.

### Potential explosives

Many common chemicals are potentially explosives and some of these are not recognized by manufacturers handling them. A drug product, for instance, exploded recently during manufacture because it was allowed to become unusually dry. Organic peroxides, which are used in making plastics, can sometimes be detonated by heat or shock, although there have been few explosions of this character. While most of these materials are not powerful as explosives go, they can become very sensitive to detonation, with serious results. Dryness, heat, and mixture with abrasive grit generally increase sensitivity, while moisture and mixture with oil, wax, or talc reduce it.

Another type of dangerous chemical, while not itself an explosive, is so rich in oxygen that it forms a violently explosive mixture with combustible materials, such as petroleum or many other organic liquids. Perchlorates, which have caused several disasters, are bad offenders in this respect. Tetranitromethane can be especially powerful in mixtures; on one occasion it was accidentally mixed with twice the usual amount of toluene, and instead of burning quietly, it exploded with sufficient force to kill ten people and injure thirty more. The infamous ammonium nitrate is quite resistant to attempted detonation when pure, but mixed with combustible materials, it can cause explosions such as the Texas City disaster. The excess oxygen of the ammonium nitrate combines with the

fuel material with explosive force, hence the need for extreme caution in preventing contamination in transit.

### Safety first

In dealing industrially with recognized high explosives, standard safety practices include isolation of the plant, limitation of the amount of material in any one operation, construction of suitable barricades, provision of structures which will yield to the explosion, and desensitizing of the explosives. Although many common high explosives will withstand drastic treatment without detonating, non-violent decomposition on aging or from heat may lead to an impure explosive of increased sensitivity.

On the other hand, many high explosives, will burn smoothly when ignited and unconfined, and then show little tendency to detonate. A large quantity of TNT, for instance, spread thinly will burn quietly, while the same amount compressed in a heap will begin to burn, and may then explode without further warning. A theory has been advanced that there is a critical mass for any explosive compound, and that surface ignition of this mass will be unattended by explosive violence until some critical point is reached, at which the heat and pressure generated by the burning exterior have speeded up the oxidation reaction within the mass to the point where detonation occurs. The presence of a large mass, several thousand tons, has apparently contributed to the numerous ammonium nitrate disasters.

Rubber is a difficult substance to investigate chemically, one reason being its enormous molecular weight.

## Early Detection Method Casts Light On General Nature of Cancer

# Cancer Test in Albumin Coagulation

by CHARLES B. HUGGINS

*There is hope that in a few months or a year or so you can have a cancer detection test, thanks to research by Dr. Charles B. Huggins, professor of surgery of the University of Chicago. A few years ago Dr. Huggins worked out a treatment for one form of cancer, cancer of the prostate gland, which can be controlled by a minor surgical operation or the administration of female sex hormones to counteract the male sex hormone that stimulates the un-*

*ruly growth of that kind of cancer. Use of proteins as measuring devices in cancer was described by Dr. Huggins speaking as guest upon the Science Service "Adventures in Science" program over the Columbia Broadcasting System. The first-hand account prepared by Dr. Huggins is presented to CHEMISTRY readers because it is an illuminating description of an important development in chemistry applied to medicine.*

► CANCER RESEARCH is one of the youngest branches of science, even younger than radio-activity or atomic research.

Actually cancer research is a lusty infant of 46 years. The experimental approach to cancer began in 1903 when the Danish pathologist Jensen was able to find a tumor in a rat, which was transplantable. Jensen was the first to be able to take small bits of the sarcoma of the rat and insert it in the muscle of other rats, thus transmitting the disease and giving the research workers in cancer something on which to experiment. In the 46 years since Jensen a great deal has been learned about this highly complex problem of abnormal growth called cancer.

There are fashions in science as in ladies' apparel and the herd instinct is strong. Someone uncovers a likely lead and the pack follows him in full

cry. The early experiments were largely qualitative and did not lend themselves to exact measurements.

In fact, one of the great defects in cancer research has been the lack of methods for precise measurement; except in a few cases, the measuring devices have been very coarse. Yet in all of the branches of science the value of exact measurements has been demonstrated abundantly. The greater the precision the more effective and certain have been the results.

One of the standard approaches of chemists and physicists, for which they are often chided in an amiable way, is extending the number of figures to the right of the decimal point. Very often, however, results of great value were achieved thereby. Yet in cancer research due to the complexity of the problem the results frequently could not be expressed in whole numbers to say nothing of decimals.

## Proteins Detect Cancer

The proteins of the blood serum have provided means whereby the presence and activity of cancers in certain instances can be detected with ease and precision. The serum proteins may be divided into two types; enzymes and non-enzymatic proteins. Both are valuable in the recognition of cancer and for research purposes.

The enzymes are catalysts that greatly speed up reactions which otherwise proceed at a very slow rate in their absence. All of the known enzymes are proteins. Three enzymes of the serum are of interest in cancer.

(1) *Alkaline phosphatase* is an enzymic protein made by the cells which form bone, technically the osteoblasts. This enzyme is increased in the blood whenever there is abnormally large formation of bone so that it is increased in bone tumors.

(2) *Acid phosphatase* is another protein which is increased in the blood in cancer of the prostate. One of the serious things that cancer does is to invade adjacent tissues and blood vessels and spread itself through the body. When cancer of the prostate spreads beyond its original confines the enzyme acid phosphatase increases to high levels. The activity of this cancer may be studied from day to day by determining this enzyme in the blood stream and the resulting curve when plotted depicts what is going on in the cancer in as elegant a way as a chart of a patient's body temperature reveals the course of fever and the evolution or regression of the disease.

By studying these proteins the acid and alkaline phosphatase enzymes of

serum it was demonstrated that certain cancers of the prostate required the male sex hormone as an essential nutritional element; when these hormones are removed by a minor surgical operation or counteracted by giving the female sex hormones often very wide spread cancers shrink with great benefit to the patient. Precise measurements made possible this first proof that wide spread cancer of the prostate in man is capable of undergoing a pronounced and prolonged remission by very simple means.

(3) The third enzyme *aldolase* of value as a measurement of cancer activity is concerned with the metabolism of glucose; this protein enhances the breakdown of glucose on its way to carbon dioxide and water. Glucose has six carbons and aldolase catalyzes its breakdown to two fragments, each containing three carbons. In tumors in the muscle of rats, the aldolase of serum is increased, the level corresponding in a general way to the size of the tumor and it is also increased in certain humans with cancer as well.

## Albumin of Blood Abnormal

The non-enzymatic proteins of blood serum have been studied more recently, and, like the enzymes, they have been shown to be adaptable to precision measurements in cancer. In brief, in man who is the victim of cancer, the albumin of the serum is frequently abnormal. This was shown by studying the coagulation of blood serum when it was heated.

Thermal coagulation is one of the commonest every day operations of the kitchen: when one boils an egg, the albumin and other proteins change

from a clear liquid to an opaque solid which we call hard boiled. What happens, in essence, is that the globular protein of egg albumin changes to a fibrous state. Accompanying this unfolding there is a liberation of sulphydryl groups (sulfur-hydrogen) which previously had been coiled in the globular protein and upon liberation of hydrogen a sulfur to sulfur bonding takes place.

When human serum is heated in a tube of boiling water the same process takes place; solidification, cloudiness and the formation of sulfur to sulfur bridges to form a three dimensional lattice.

This was proven in the following way. The chemical compound iodoacetic acid at neutrality, provided a minimum quantity is present, has the peculiarity of preventing coagulation of egg white and also of human serum. No matter how long they are heated neither of these proteins becomes hard boiled. Iodoacetic acid, due to the nature of the compound and especially the iodine content of the compound, has a greater attraction for the sulphydryl groups; the iodine of the molecule combines with the hydrogen of the sulphydryl and the acetic acid thus set free unites with the sulfur. Accordingly, the sulfur molecules having an acetate group adherent to them cannot dispossess themselves of that group and so cannot unite and hence cannot coagulate.

If somewhat less than the minimum quantity of iodoacetic acid is added to egg albumin or human albumin and the mixture is boiled a very curious effect is observed. The albumin coagulates but does not be-

come cloudy: instead a translucent glassy state occurs. The hard boiled proteins have rubbery elastic qualities and may be stretched considerably and will recoil when tension is released, but the strangest property is their translucency: one can read a newspaper through the hard boiled proteins so glassy they are.

The opacity of serum or of a hard boiled egg is due to the cross linkages of sulfur atoms and its "hardness" is due to arrangement in parallel bundles of amino acid polymers of rather long length. Iodoacetic acid first blocks the side chain binding and in larger amount prevents the formation of long chains, hence the protein remains liquid.

#### How Test Is Done

The protein of cancer serum is defective in coagulating groups. We mix in a series of separate tubes a constant amount of serum, 0.25 cc., with increasing amounts of iodoacetic acid and place the tubes in boiling water for 30 minutes. The tubes are then tipped to find out whether the serum has been coagulated, in which case it will not pour, or whether it is liquid. The smallest concentration of iodoacetic acid to prevent serum from becoming solid on heating is the end point in which we are interested. The serum of most patients with cancer requires far less iodoacetic acid than is required by normal serum.

The test is not specific for cancer. The blood serum from patients with tuberculosis of the lung acts like cancer blood. However, the important thing is that the presence of cancer in an individual upsets the mechanism whereby the serum albumin is

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A great deal of evidence points to the liver as the organ of the body where serum albumin is made. We are of the opinion that the cancers depress the synthetic activity of the liver so that it makes faulty albumin. Other facts previously gathered point in this same direction. Greenstein and Andervont at the National Cancer Institute have performed some ingenious experiments in this regard. They transplanted a tumor to the tails of mice and determined the content in the liver of a protein which was also an enzyme called catalase (catalyzes liberation of oxygen from hydrogen peroxide). When the tumor transplants grew the catalase content of the liver decreased greatly. Then they cut off the tail thereby ridding the mouse of the tumor. The catalase content of the liver promptly rose to normal. Like catalase, serum albumin formation is interfered with by cancer.

Albumin is the most abundant fraction of the proteins of blood plasma. Albumin has a variety of functional purposes in the organism. It has a relatively low molecular weight for proteins of 70,000 and has a tremendous attraction for water. It is one of the chief agents which prevents the tissues from becoming water logged

under normal conditions. Water logged tissues (edema or dropsy) occurs when the albumin is decreased through loss in kidney disease or when it cannot be made by the body as in areas of famine. This occurred often in the famines of India and also Germany during World Wars I and II.

Serum albumin has another functional use, namely as a carrier of drugs, hormones and other substances of great importance to the organisms. Hemoglobin is a protein which builds oxygen releasing it to the tissues when and as it is needed. The albumin of serum in its turn carries many essential agents to the tissue cells.

### Summary

In cancer the albumin of the serum is frequently altered profoundly as is recognizable by its deficient content of those groups which participate in heat coagulation. This phenomenon in our laboratory has some utility as a practical test for the presence of cancer and other diseases; it is a rough screen which distinguishes at least between sickness and health. It is of interest that cancer causes a severe constitutional disturbance of one of the most important proteins of the body, the serum albumin. The chief interest is in what light the disturbed albumin casts on the general nature of the disease called cancer.

Paraxanthine, a chemical compound somewhat similar to caffeine and found in the liver of various animals, is called an anti-thyroid substance because it has the opposite effect to that of thyroid hormone.

Most sugars are sweet, but lactose, the sugar of milk, is not; it gives the bland distinctive taste to milk and milk products.

Patent Issued on TVA Process  
For Defluorinating Phosphate

## Furnace Makes Better Fertilizer

► BETTER PHOSPHATE fertilizer at lower cost is the promise of a process for cheaply and efficiently taking the harmful fluorine out of it during the smelting process, on which U.S. patent 2,474,831 has just been issued to a chemist on the staff of the Tennessee Valley Authority, Dr. Kelly L. Elmore of Sheffield, Ala. Rights in the patent are assigned royalty-free to the government.

A vertical smelting furnace is charged with a mixture of lumps or briquets of crude phosphate rock and similar-sized pieces of silica. Fuel is preferably gas or oil, though coal or coke may be used. Water vapor produced during combustion of the gas or oil fuel takes up the fluorine, which is removed for salvage as hydrofluoric acid. If the fuel is coal or coke, it is necessary also to introduce steam, to provide enough water vapor for the reaction.

The chief mineral in the phosphate rock is fluorapatite, whose composition follows the formula  $\text{Ca}_{10}\text{F}_2(\text{PO}_4)_6$ . It is not readily used by plants, and the object of the process on which the patent has been granted is to convert it into a more useful fertilizer and get rid of the fluorine, which is useful in other ways.

Earlier methods for accomplishing this result have been by melting the phosphate rock in furnaces lined with corrosion-resistant material. These are costly to build and expensive to operate, while the phosphate fertilizer they

turn out must compete on the market with similar material from very cheap sources.

The present inventor finds that he can use a conventional type of furnace, without an expensive lining, by making the rock itself act as its own insulating material. In this way corrosion of equipment and heat losses through furnace walls are minimized. At the same time the fluorine content is reduced to below 0.6 per cent in one operation.

"I have now found," states Dr. Elmore, "that these objects may be attained by charging phosphate rock in admixture with silica in excess of the quantity required to satisfy the following equation:  $\text{Ca}_{10}\text{F}_2(\text{PO}_4)_6 + \text{H}_2\text{O} + \text{SiO}_2 \rightarrow 3[\text{Ca}_3(\text{PO}_4)_2] + \text{CaSiO}_3 + 2\text{HF}$  and preferably in the range from about 18 per cent to about 27 per cent of the total charge, into a vertical reaction zone in discrete lumps or masses; continuously directing a stream of hot combustion gases, containing water vapor in proportion not less than 4 per cent and preferably in the range from about 10 to about 20 per cent of the total combustion gases, substantially vertically upward against the bottom of the charge."

Since the walls of the furnace taper inward above the hearth at the bottom, to form a constriction known as a "bosh," the charge of rock catches there and the hot gases find their way upward through the center of the

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charge. The inventor describes the operation of the furnace as follows.

It is preferable to begin operation by starting the burner and directing the combustion gases from the hydrocarbon fuel vertically upward through the central part of the furnace shaft. The charge of crushed phosphate rock is then added at the top until the upper surface is from thirteen to eighteen feet above the hearth.

The stream of hot combustion gases is passed upward continuously. After a period of time which varies with the charge and the conditions of operation, fire begins to show through a central part of the upper surface of the charge. When this occurs, the central part of the upper surface of the charge appears, to an observer at the access door, to have sunk or fallen, forming a crater.

A fresh portion of charge is then added to the upper central portion of the body of the charge in the furnace. Heating is continued with addition of fresh portions of charge whenever fire shows through and the central part of the charge appears to have sunk or fallen. At intervals molten, defluorinated tricalcium phosphate is withdrawn from the hearth of the furnace, through a tap hole.

The exact mechanism by which melting occurs in this process is unknown, as no one can observe the interior of a charge of melting rock, where the temperature is of the order of  $1500^{\circ}\text{C}$ . Observation at the access door merely shows that during operation a crater or depression forms at a central upper part of the charge and that the flame often shoots up from the center of this crater rather like a volcano. This is "blacked out" by

charging fresh material.

Investigations of furnaces which have cooled down show that there is sometimes present in the cooled mass of charge a tortuous "chimney," extending from the upper surface to the bottom of the charge. More often there is merely a depression in the upper part of the charge, surrounded by a raised rim of sintered charge.

However, it is certain that an arch is formed at the bottom of the charge, just above the hearth, and that the greater proportion of melting occurs on the surface of the arch and on that part of the charge extending vertically upward through the central part of the furnace.

A charge having the composition described above has been found to have certain unexpected properties which make this process operable. The individual masses sinter or adhere to the furnace walls and to each other with sufficient strength to form an arch in the bosh and to prevent the melting charge from collapsing into the hearth of the furnace.

The individual masses melt on their surfaces exposed to the stream of hot combustion gases without softening in their interiors sufficiently to permit the mass of charge to settle under its own weight and to close off passages for gases through the body of the charge.

As a result of these properties, hot gases flowing upward through voids in the body of the charge come into intimate contact with surfaces of individual masses. Melting occurs on these surfaces and the resulting molten material trickles down over lower portions of the charge in intimate countercurrent contact with hot gases contain-

ing water vapor, and is effectively defluorinated.

The molten material need descend only a few feet in contact with the gas stream for the greater part of its fluorine content to be transformed into volatile compounds and to be vaporized by the melt. While the inventor prefers to use a body of charge having a depth of at least ten feet, this preference is based upon economies of heat transfer. If hot gases flow through a thin layer of charge they emerge at very high temperature and so much heat is lost in overhead gases as to increase greatly the expense of the process.

The molten material withdrawn

from the hearth of the furnace is impure tricalcium phosphate in which the fluorine content may consistently be well below 0.6 per cent, and may often be as low as from 0.2 to 0.3 per cent.

When it is desired to prepare a product having sufficiently low fluorine content to be suitable for animal feeding (less than 0.1 per cent fluorine) this may be done by withdrawing the molten product from the hearth of the furnace, cooling it and forming it into discrete lumps, charging these into a furnace and repeating the above described process. The second treatment reduces the fluorine content to the desired degree.

## New Patents With Chemical Angles

### Fertilizer From Wastes

► A MACHINE for the rapid conversion into high-humus organic fertilizer of such wastes as sewage sludge, garbage and offal from food-processing plants is offered by Eric W. Eweson of New York for patent 2,474,833. It undertakes to do quickly and under controlled conditions what has been accomplished much more slowly by traditional composting.

The wastes, inoculated with suitable bacteria, are charged into a vertical cylindrical container, which is provided with inlets from an air compressor and with a motor-driven stirrer. The accelerated composting process goes on as the material slowly works its way downward, until it is discharged as finished fertilizer through a port at the bottom.

### Olive Essence

► A CONCENTRATED, highly flavored "olive essence" can be produced from

crushed or ground olive pits by extraction with a mixed solvent consisting principally of methylene chloride, states Frank C. Battistella of New York, in patent 2,475,419. After the solvent has been distilled off, the olive essence can be used for converting less highly esteemed food oils into acceptable substitutes for olive oil. One possibility, of undoubted interest to the weight-reducing sisterhood, is the use of olive essence for the production of an agreeable-tasting, but calorie-less, salad dressing by flavoring up tasteless mineral oil.

### Copper Without Creep

► COPPER used in turbogenerator windings is cured of its tendency to "creep" between stops and starts by alloying it with just a little silver—between 25 and 100 pounds per ton—in the invention on which patent 2,474,891 was granted to Evan A. Davis

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of Forest Hills, Pa., assignor to the Westinghouse Electric Corporation.

#### Wood Chip Digester

► A CONTINUOUS-PROCESS method for digesting wood chips, in the preparation of industrial cellulose or wood sugar, is covered by patent 2,474,862, issued to a Norwegian chemical engineer, Johan C. F. C. Richter, of Oslo. Pressure is continuously maintained in the long cylindrical digester, and the wood chips are forced in against this pressure by means of screws. The product is discharged at the bottom.

#### Slurry Coal Salvaged

► COAL-DUST suspended in water, known to the trade as slurry coal, has long been a troublesome waste in the coal-washing industry. Andrew F. Howe of St. Louis has worked out a method for its salvage, involving first screening it to remove too-coarse particles, then wringing it dry in a centrifuge, and finally spreading it on a conveyor that carries it through a special oven or "devolatilizer" where gases are driven off and used as fuel. The coked powder is then pressed into briquets for home or industrial use. Patent 2,474,251 has been issued on this invention.

#### Electrolytic Control

► To AID in the modern method of manufacture of metal coated or plated materials, such as tin-plate, by the electrolytic process, a control has been developed with means for supplying the variable amounts of electric current for the process, and means for effecting the travel of a length of material through the electrolytic bath at different speeds. It is for use in the continuous process in which a long length of the material to be coated travels at a more or less constant rate through

the bath, with the thickness of the coat deposited depending upon the length of time the material is exposed to the plating current and the density of the plating current.

The control functions by varying the speed of travel of a strip through the bath by varying the current flow in the process. This automatically varies the speed of the strip in accordance with the current flow. Patent 2,471,912 was granted to Glenn E. Stoltz, Pittsburgh, John R. Erbe, Mount Lebanon, and Ralph A. Geiselman, Wilkinsburg, Pa., for this invention. It has been assigned to Westinghouse Electric Corporation, East Pittsburgh.

#### Protein Gel

► FEATHERS and hog hair are farm wastes that can be converted into a versatile protein gel, good for either animal feed or use as a horny, clear plastic, by the process on which patent 2,474,339 has been issued to W. H. Ward and C. H. Binkley of Berkeley, Calif. Conversion is effected by heating in alkalinized alcohol. Rights in the patent are assigned royalty-free to the government.

#### Answer to Crossword Page 28



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